DOCUMENT RESUME

ED 307 398 CE 052 438

AUTHOR	Markley, O. W., Ed.
TITLE	Preparing for the Future of the Workplace. Volume II: Analytical Studies.
INSTITUTION	Institute for Strategic Innovation, Clear Lake Shores, TX.; North Harris County Coll., Houston, Tex.
SPONS AGENCY	Texas State Higher Education Coordinating Board, Austin. Div. of Community Colleges and Technical Institutes.
PUB DATE	Jun 88
NOTE	155p.; For related documents, see ED 293 001 and CE 052 437-439.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	Community Colleges; Coordination; Dislocated Workers; *Economic Development; *Educational Cooperation; Educational Planning; Educational Technology; Employment Patterns; Females; Futures (of Society); *Information Technology; Minority Groups; Postsecondary Education; Role of Education; Statewide Planning; Technical Education; Technical Institutes; *Technological Advancement; Two Year Colleges; *Vocational Education

ABSTRACT

This volume is the second of three reporting research that is intended to help postsecondary occupational education deans and directors become able to plan more strategically for using new instructional technologies to meet emerging needs. The document contains the findings from three background studies in three chapters. "Emerging Information Technologies of Significance for Postsecondary Occupational Education" (Christopher J. Dede) is divided into two parts. Part 1 presents two scenarios that demonstrate the technical advances, with 94 references. Part 2 discusses the functions that are emerging as the result of work in the information technologies. These are divided into three themes: knowledge representation, user interfaces, and computer-supported work. Then, the hardware evolution that will support the implementation of these capabilities is summarized. The next chapter is "Technology-Related Occupational Displacement and Training Needs, Especially among Women and Minorities" (Karla M. Back, O. W. Markley). It defines job displacement and technology-related changes in occupations, explores causes of job displacement and costs of technology-related job displacement, and addresses considerations and options for the future, concluding with 23 references. "Public-Private Initiatives as a Policy Option for Improving Occupational Education" (Paul C. Fama, Karla M. Back, O. W. Markley) analyzes how collaboration could be used for new initiatives that link economic development and vocational education planning. A 25-item bibliography is included. (YLB)

ED307398

PREPARING FOR THE FUTURE OF THE WORKPLACE

VOLUME II: ANALYTICAL STUDIES

Prepared for:

The Texas Higher Education Coordinating Board
Community Colleges and Technical Institutes Division

By:

The Institute for Strategic Innovation

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

Minor changes have been made to improve reproduction quality.

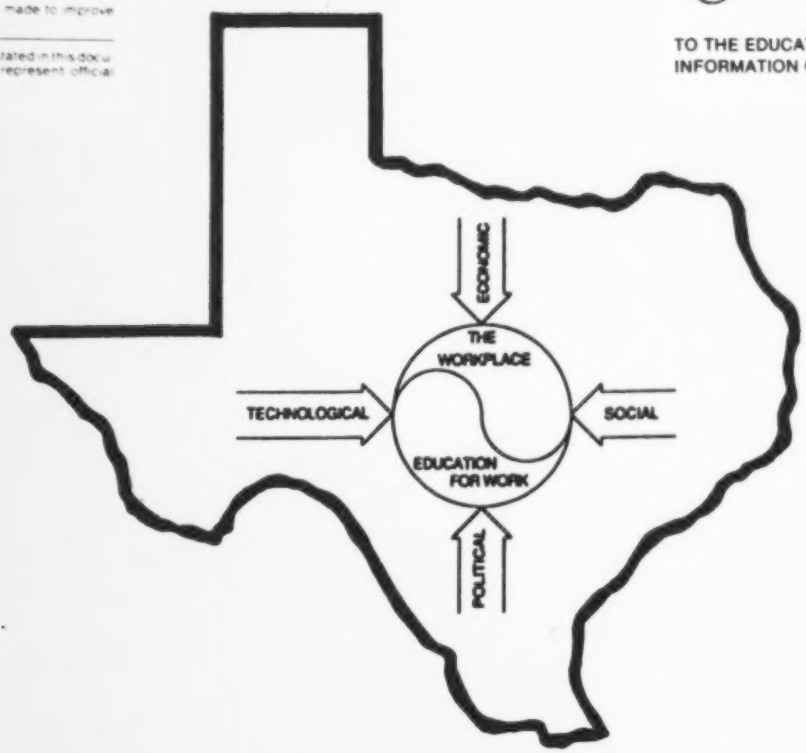
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

June, 1988

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

O W Markley

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."



CE052438

The Institute for Strategic Innovation
P.O. Box 1039 • Clear Lake Shores, Texas 77565 • 713/334-2606

BEST COPY AVAILABLE

PREPARING FOR THE FUTURE OF THE WORKPLACE

a project undertaken by the Institute for Strategic Innovation
under subcontract to the North Harris County College

Research Team

Karla M. Back
Christopher J. Dede
Paul R. Fama
O. W. Markley

Advisory Committee

John Cavnar-Johnson
Geoffrey H. Fletcher
Nellie C. Thorogood
Kenne G. Turner

This project was funded by the Carl D. Perkins Vocational Education Act, Series PVEP-1000 IV-A, Project No. 88-1000-02-02

© 1988 The Institute For Strategic Innovation

EXECUTIVE SUMMARY

Much has been accomplished since the Master Plan for Vocational Education in Texas was formally approved by the Higher Education Coordinating Board in October, 1986, and by the Texas Education Agency in January, 1987, and formally became law with the passage of HB 72. The Master Plan thus has a legal mandate to provide strategic planning directions for occupational education,[1] and public education institutions are required by law to comply.

An even broader planning process is now underway by the Texas Strategic Economic Policy Commission, which is scheduled to release a draft of its strategic plan for the State in mid-July, with hearings on the draft report to occur during August and September, and the final report to be approved by the Governor and released before the end of the year. Because the thrust of this Commission, like that of several previous task forces, is to stimulate economic diversification and development, including the improvement of occupational training in needed new skill areas, it also will set major directions which educators will be required to follow.

The research reported here is intended to help deans and directors of community colleges and technical institutes implement planning objectives which comply with the above requirements--especially those set forth in the Master Plan focusing on the development of educational delivery systems based on:

- Emerging needs
- Competitive, cost-effective, state-of-the-art training technologies

---

[1] For convenience we use the term "occupational education" to refer also to "vocational and/or technical education."

. Resource funding and implementation via public-private collaboration, rather than by the public sector only.

It follows an earlier working paper entitled, The Future of the Workplace in Texas: A Preliminary Identification of Planning Issues for Technical, Vocational, and Adult Postsecondary Education, which had the same substantive focus, but was aimed at illuminating policy questions asked by the professional staff of the Coordinating Board in connection with Master Plan implementation.

To make it easier for you to read and use this report, we have: 1) written much of it in the active voice; 2) divided it into three volumes, each of which has the same front matter so that you may either bind them together or separately; and 3) drawn together a selected "Packet of Guidesheets" made up of materials from all three volumes. It is appended to the Executive Summary of Volume I, beginning on page vi.

Many of you may find Vol. III the most useful, because it leads off with a practical set of planning methods and guidelines for utilizing emerging instructional technologies. It then presents more advanced materials: 1) a method for developing the "intelligence" needed for effective management of change in public-private settings; and 2) a forecast of technological, economic, social and political "factors" you can read to better understand the complex variety of trends and issues that are likely to impact occupational education in the future. Finally, in the last chapter, we present the results of a needs assessment conducted to ensure that our materials would meet the expressed needs of deans and directors.

Vol. II contains the findings from three background studies:

- A description and forecast of emerging information technologies, especially those with significance for vocational education;
- An analysis of technology-induced job displacement, especially as it affects women and minorities;
- An analysis of public-private collaboration, especially as it could be used for new initiatives which link economic development and vocational education planning.

Vol. I provides an overview of the entire project, including a summary of important factors and planning issues that you may find useful to consider. It ends with a description of how we followed the methodology we describe in this report as we did the research, and includes some surprises we found as we did so. They provided us with insights we think may be useful for you as well. Appended to Vol. I is information about the Institute for Strategic Innovation, the research team, and acknowledgements.

Together, these three volumes are intended to help you strengthen the institutional capacity of the community college and technical institute system in Texas to engage in education planning for economic development.

The main sections of the three volumes are:

Volume I: Overview

Executive Summary

Packet of Guidesheets

Chapter 1. Vocational Education Planning for Economic Development in Texas, by O. W. Markley

Appendix: Acknowledgments, Project Personnel, and Institutional Description

Volume II: Analytical Studies

Executive Summary

Chapter 2. Emerging Information Technologies of Significance for Postsecondary Occupational Education, by Chris J. Dede

Chapter 3. Technology-Related Occupational Displacement and Training Needs, Especially Among Women and Minorities, by Karla M. Back and O. W. Markley

Chapter 4. Public-Private Initiatives as a Strategy for Promoting Effective Implementation, by Paul C. Fama, Karla M. Back and O. W. Markley

Volume III: Planning Materials for Educators

Executive Summary

Chapter 5. Planning to Use Emerging Instructional Technologies: Some Useful Methods and Guidelines, by O. W. Markley, Chris J. Dede, and Karla M. Back

Chapter 6. Intelligence Information for Future-Responsive Planning and Management, by Chris J. Dede and O. W. Markley

Chapter 7. A Needs-Assessment Survey of Deans and Directors in Texas, by Karla M. Back and O. W. Markley

CHAPTER 2

EMERGING INFORMATION TECHNOLOGIES OF SIGNIFICANCE FOR POSTSECONDARY OCCUPATIONAL EDUCATION

By:

Christopher J. Dede

CONTENTS

Part One: Emerging Instructional Technologies

Introduction..... 1

Emerging Capabilities of Advanced Instructional Technologies..... 3

Historical Development..... 4

Instructional Technology Forecast..... 7

Cognition Enhancers..... 7

Scenarios..... 15

Timetable..... 21

Evolution..... 21

Summary..... 25

Implications for Occupational Education..... 26

Conclusion..... 31

References..... 33

Computer Hardware..... 77

Architectures..... 80

Secondary Storage..... 84

Telecommunications Hardware..... 89

Augmenting Capabilities..... 90

Increasing Connectivity and Integration..... 94

Hardware Integration and Long-Range Evolution..... 96

EXHIBITS

2.1 An Approximate Timetable of Emerging Technologies for Instruction..... 22

2.2 Evolution of Instructional Technologies by 1995.... 24

2.3 MicroVax System Comparison..... 81

2.4 Optical Vs. Conventional Mass Storage Systems..... 87

2.5 Increasing Telecommunications Capacity..... 90

2.6 Satellite System Bit Rates..... 93

2.7 Growth in Satellite Capacity..... 93

PART ONE: Emerging Instructional Technologies

Introduction

We live in a time of rapid increase in power of information technologies. Almost daily, expanded capabilities for some aspect of computers or telecommunications are announced. Simultaneously, the cost of these devices, relative to what they can accomplish, is dropping rapidly. Some claim that these advances herald a new era: industrial society is being replaced by a civilization based on information. Others doubt that the change will be so drastic, but do see massive occupational changes occurring as people use information technologies to aid in their work.

Postsecondary vocational, technical, and adult education is doubly affected by these trends. First, as job roles alter due to information technology, the goals, content, and clients of occupational instruction must shift in response. Second, educational methods and skills are changing in response to emerging technologies that allow more efficient and effective delivery of instructional services. This chapter focuses on the latter issue: the pedagogical implications of advanced information technologies. (Contrasting views on the former issue can be found in Spenner [1985], Dede [1985a], Marshall [1987], and Burke & Rumberger [1987].)

This section, Part One, summarizes the emerging capabilities of some advanced instructional technologies. This prediction covers a time period from the present through the next two decades into the early years of the twenty-first century and incorporates the overall forecast for the evolution of information technology given in Part Two.Such an analysis has two purposes. First, it allows educators to anticipate opportunities for innovation by

scanning the fields of research likely to have a major impact on the development of instructional technology. Second, it provides a realistic time frame for when a technical advance will be widely available at affordable cost--important knowledge for strategic planning.

Part One also presents an assessment of what these improved functionalities might mean for postsecondary vocational, technical, and adult education. Isaac Asimov once said that the important thing to predict is not the automobile, but the parking problem; not the television, but the soap opera. Similarly, the vital issue is not how many computers will be in classrooms by the year 2000, but how relationships between teachers and students, postsecondary institutions and society will alter as a result.

Overall, this synthesis of research discusses the potential of advanced information technology to reshape occupational instruction. (Improvements in educational administration at classroom and institutional levels, while significant, are beyond the scope of this chapter.) Whether this potential will be realized is a different matter; successful innovation is not solely dependent on technical capability. Instructional technology has a mixed track record in terms of its cost effectiveness and utility, partly because less-than-optimal implementation approaches have been used in the past. Chapter 2 in this report, **Planning Guidelines for Utilizing Emerging Instructional Technologies**, delineates some practical strategies that postsecondary vocational, technical, and adult educators can apply in planning for new pedagogical devices and delivery systems.

Emerging Capabilities of Advanced Instructional Technologies

This section synthesizes research from a variety of fields--computer science, telecommunications, artificial intelligence, cognitive science. It forecasts probable technical advances in each field, but focuses on functionality (what a device will be able to do), since predictions of increased performance often overshadow the problem of applying a new technology. For example, the number of MIPS (Million Instructions Per Second) a thirty-two bit microprocessor might handle by 1995 remains an abstract statistic until translated into the workplace via advanced technology.

Part One presents two scenarios that demonstrate the technical advances discussed.The timetable that follows lists each functionality by use and likely availability. (For example, an instructional device with a capability for voice recognition--user-specific, limited-vocabulary--is technically feasible at reasonable cost by the late 1990's.) Of course, these projections are speculative, since the future is uncertain and even experts often disagree as to when a technical functionality may be realized. Part Two categorizes by field projections for technological advances (e.g., in knowledge representation, in computer-supported cooperative work) rather than grouping them arbitrarily in a single scenario. Such an approach allows presenting a menu of suggested references to readers who wish to learn more about work of particular interest.

This section has two goals: to expand the reader's awareness, and to enhance his ability to plan for the future. Advances in information technology occur rapidly. Scattered as they are over many fields, their potential for improving instruction is currently not widely

understood. Will inexpensive devices, as some claim, revolutionize the process of teaching? Or, is the extensive use of instructional technology an expensive and ill-conceived fad? By presenting a synthesis of leading-edge research with a forecast for the availability of certain technology, this chapter should allow the educator to make more informed judgments about potential applications in his field.

Historical Development

Since the Forties, the power-per-unit cost of information technologies has increased exponentially. Performance characteristics of computers and telecommunication devices--speed, memory size, bandwidth--have repeatedly doubled every few years at constant cost. As discussed later, this trend is expected to continue for at least another decade before fundamental physical limits (the speed of light, entropy, quantum mechanics) pose significant barriers to further advances.

How rapid have these increases been? Ten years ago $3,500 could buy an Apple II microcomputer with an eight-bit, one-megahertz processor, 48 Kilobytes (K) of RAM, 8K of ROM, a 40-character by 24-line upper-case display, high-resolution graphics (280 by 192 lines of resolution, 16 colors), two 140K disk drives with controller, and a Radio Frequency (RF) Modulator to connect with a television set. Adjusting for ten years of inflation, an equivalent amount of purchasing power today is $6,800. For that price, one can buy a Macintosh II with a 16-megahertz, 32-bit processor, one megabyte of RAM, 170K of ROM, two 800K disk drives with controller, a 20 megabyte hard disk, and a 640 by 480 RGB display with 256 colors. This microprocessor can handle four times the information at sixteen times the speed, its total internal memory is about twenty times larger, total external memory about

seventy-five times larger, and a display is now included with seven times the resolution and sixteen times the number of colors. Comparable figures can be cited for machines from other vendors.

Such exponential growth, with each successive doubling of power, adds an equivalent amount of capability to all that has historically existed. As these trends continue, by early in the twenty-first century we can expect all the microcomputer power available now to double, double again, and again, and again and again. Equally amazing, user demand for this power has increased as rapidly as it has become available. In the mid-1960's, IBM debated whether to use 6-bit or 8-bit channels for its largest computers (which were considerably less powerful than today's Macintosh II). Those arguing for the former maintained that the extra capacity would not be needed, since users would never want lower-case alphabetical capability on their machines! Those early line-editor applications for text have since been displaced, first by word processors and lately by desktop publishing. Meanwhile, customer demand continues to push the limits of state-of-the-art microcomputer hardware.

Prompting this evolution is a shift in the perceived functionality of information technologies. The original forecast for the total U.S. market for computers was less than ten, because these devices were seen as large, expensive "number-crunching" machines. As prices fell and capabilities increased, the concept of "data processing" arose, and many new applications developed. Now, as will be discussed later, a new paradigm of "symbol manipulation" is emerging; coupled with increasing functionality, this is creating a still larger demand for information technology.

Over the next two decades, data processing and information systems are likely to be displaced by sophisticated devices for knowledge creation, capture, transfer, and utilization [Dede, Sullivan, & Scace, 1988]. A similar evolution can be traced for telecommunications, with personal videorecorders, optical fiber networks, "intelligent" telephones, information "utilities" such as videotex [Dede, 1985b], and digital discs all helping to shift the fundamental nature of communications media.

Users can easily forget how rapid this advance has been, since our civilization swiftly absorbs new technologies and alters institutional patterns to create instant traditions. For example, spreadsheets are now commonplace in information-based occupations; yet this extremely useful application first appeared only a decade ago. Employers and educators tend to think of power (speed, capacity) in terms of existing functions (e.g. more rapid searches through databases), rather than innovative approaches to storing information in associative networks ("hypermedia", p. 45).

Typically, new information technologies impact institutions in four stages [Coates, 1977]:

Stage One: An institution adopts a new technology to more effectively carry out existing functions.

Stage Two: The institution changes internally (work roles, organizational structure) to take better advantage of these new efficiencies.

Stage Three: Institutions develop new functions and activities enabled by additional capabilities of the technology. As the roles of different types of institutions expand, new competitive relationships emerge.

Stage Four: The original role of the institution may be radically transformed as new goals direct its activities.

Workplace tools are just beginning to enter Stage Three for the early 1980's generation of microcomputers, and are at Stage One for the 32-bit machines now emerging. Pedagogical tools (educational institutions being slower to adapt) are reaching Stage Three for the 8-bit personal computers of the late 1970's. Generally speaking, the same holds true for recent telecommunications technologies.

Instructional Technology Forecast

The reader should now prepare himself to visualize mature Stage Three applications for instructional technologies in his or her particular field of postsecondary vocational, technical, adult education. This could prove a difficult task. Many professionals merely graft new tools onto their already developed strategies, which greatly limits the pedagogical potential of these devices. This may not be realized until a new generation of teachers, having been bred on such technologies, creates a new instructional paradigm to guide its efforts.

Cognition Enhancers

One way to comprehend the emerging functionalities described here and in Part Two is via the concept of "cognition enhancers." (The material following is excerpted and condensed from a longer article on this subject, [Dede, 1987].) A cognition enhancer uses the complementary cognitive strengths of a person and an information technology in partnership. For example, computers have large short-term memories (megabytes of RAM), while human beings are limited to an immediate storage capacity of less than ten chunks of information [Anderson, 1983]. Computers can also execute complex "algorithms" (precise recipes for solving specific

problems) more rapidly than people. For tasks involving manipulation of successive symbolic results (e.g. involved mathematical calculations), indeed for most forms of standardized problem solving, these two cognitive attributes give computers the edge over human beings.

However, people store information long-term in "semantic networks" containing webs of associationally related textual, temporal, and visual imagery. For example, in a human memory the word "apple" conjures up religious, corporate, computational, botanic, and gustatory dimensions. At present, computers are much more limited in how their information can be interrelated, as anyone who uses a database knows. The cognitive attributes of human beings give them an advantage over computers when applying peripheral real-world knowledge to ill-structured problems (such as diagnosing the source of a student's motivational difficulties). In general, people are still much better than computers at problem recognition, metacognition (thinking about thinking), and non-standardized problem solving.

Because of current limitations of computers, cognitive science, and artificial intelligence, developing devices capable of independent instruction is very difficult. While intelligent machine-based tutors and coaches will gradually become useful in educational settings, cognition enhancers that combine the cognitive strengths of humans and computers will evolve much more rapidly. Though these tools are still in their infancy, three distinct kinds seem to be emerging.

Empowering Environments

This type of cognition enhancer utilizes the computer's strengths in structured symbolic manipulation to empower human accomplishment by a division of labor: the machine handles the routine mechanics, freeing the

operator for higher-order tasks. For example, I once took an oil painting course. My goal was to faithfully convey to a canvas the images in my mind so that viewers could share my experiences and emotions. However, rather than pondering form, composition and aesthetics, I spent my time trying to mix colors that remotely resembled my mental images, trying to keep the paint from running all over the canvas, trying to keep the turpentine out of my hair. Now, I use graphics software that allows me to choose from a huge palette of colors; to alter, pixel by pixel, the contour of an image; to instantly "undo" my failures. I am involved with the deep semantics of art, while the empowering environment handles the mechanics. (My accomplishments, however, are still ultimately limited by my own talents and knowledge as an artist.)

Primitive empowering environments are beginning to be used in education. A word processor with spelling checker, thesaurus, typing tutor, and graphics tool is the beginning of an empowering environment for writing. Even the early versions of this type of cognition enhancer have an interesting property: the user unconsciously alters the style of task performance.

For example, as a result of using a word processor, I no longer can write well with a paper and pencil. I used to compose a sentence by thinking for a couple minutes and setting down a final version that was about 90% of optimal; I "took my one best shot" because making changes later would involve massive physical cutting and pasting. Now, I write by thinking for a bit, typing in a sentence that is perhaps 40% of optimal; thinking for another few seconds, making a second change--and so on, until I achieve a final product. Using a word processor, it still takes as much time to write, but now the focus is on revising and polishing, rather than producing a single

"finished" product that one is disinclined to tinker with because of the work involved.

When I try to write the same way using a pencil--disaster! Most people who use word processors (music tools, databases, spreadsheets) experience the same unconscious shift in style. In a world of intelligent empowering environments, the ways we accomplish tasks may radically change in response to new technology.

The skills required for many occupations are shifting because of the use of similar empowering environments in the workplace: word processors and desktop publishing applications for jobs involving writing, databases for information storage and retrieval, spreadsheets for modeling and simulation, computer-assisted design and manufacturing workstations for production. As work roles increasingly involve using job-performance aids of this sort, educators must find a way to incorporate into their curriculums instruction in the use of empowering environments. Readers interested in exploring the concept of educational empowering environments in greater depth should refer to Brown [1985].

Hypermedia

Even with a sophisticated empowering environment for desktop publishing, I can still get writer's block. A second type of cognition enhancer is needed: "hypermedia" is a framework for the interconnected, weblike representation of symbols (text, graphics, images, software code) in a computer. Because long-term human memory is stored in associational semantic networks, it is sometimes difficult to access. Even when I know what I want to write, I may not be able to channel my ideas into the linear "stream" required for written and oral communication. I need an "idea processor," an external, multi-dimensional construct that will mirror the concepts

and the links between them that already exist in my memory. With my knowledge externalized into a hypermedia system, I can then traverse this network along alternative paths through nodes and links, seeking the right sequential stream for my intended content, audience, and goals. The computer is working in cognitive partnership to eliminate the overload involved in transferring long-term to short-term memory. Also, personal access to long-term memory may be enhanced by the process of building and using hypermedia.

Hypermedia (discussed in more detail in Part Two) is a general tool that can be utilized in several different ways. In addition to serving as an externalized associational memory as described above, hypermedia could function as an alternative representational system for a large, shared database (e.g., an integrated textbook series for an entire curriculum). Such an approach would encourage group interdisciplinary exploration by explicitly connecting similar ideas in different subjects. Hypermedia, as a knowledge representation format, empowers instructional design based on cognitive principles of learning such as active structural networks, schema theory, web teaching, and generative learning [Jonassen, 1986].

Hypermedia "documents" may soon be commonplace in the workplace. For example, automobile mechanics may soon be using hypermedia repair manuals to diagnose problems by tracing initial symptoms through a series of linked tests to reach a final judgment on what is wrong. By following another web of nodes which map the different steps, the mechanic can then repair your car. An educational version of such a manual would incorporate similar "trails" through a hypermedia network that guide the user through a series of structured, sequenced learning experiences.

Even primitive hypermedia systems on personal computers are likely to unleash a variety of new ideas about uses for this type of cognition enhancer. A hypermedia version of this paper, for example, would place each fundamental concept in a separate node; related concepts would be linked together (e.g. the material on semantic nets in the "cognition enhancers" section to that in the "hypermedia" section). This modular arrangement of juxtaposed data, when compared with the forced linearity of most textual presentations, should increase the user's comprehension. Perhaps new styles of remembering and knowledge transfer will evolve as well. For readers interested in further exploring the educational applications of hypermedia, the Intermedia System at Brown University [Yankelovitch, Meyrowitz, & van Dan; 1985] is a good resource.

Microworlds

This third type of cognition enhancer allows the user to explore and manipulate limited "artificial realities." A problem that learners constantly experience is how to relate abstract, concepts to real-world situations. For example, if I were explaining how Einstein's theories of general and special relativity had altered our understanding of gravity, I could approach this task by teaching the appropriate equations and formulas to my students. However, even with good reasoning skills and a background in physics and calculus, few would be able to link their abstract comprehension to real-world applications to explain such phenomena as why water swirls down drains in opposite directions in the Northern and Southern hemispheres.

What is needed is a "microworld," an artificial reality which can vary gravity's fundamental properties. Students could then use the computer to explore a

particular activity (say, baseball) at earth gravity; then, at lunar gravity; then, at Jupiter's gravity; with a brief game at zero gravity! Varying one item at a time, we could work through the constants and variables in the equations, altering each in turn to see how the game of baseball would change. Now, students would have both a formal and an applied knowledge of the theories underlying gravity.

The concept of microworlds extends to "surrogate travel" and "surrogate experience." Taking advantage of the emerging synthesis between telecommunications and computers, interactive videodiscs would allow an individualized "trip" to be taken to the Louvre in Paris. Students could "walk" through the Museum examining art objects in any order, at different angles, for any duration, with or without commentary, with hypermedia links to related subjects. This experience would not be the same as actually visiting the Louvre, but would be far more instructive and motivating than merely viewing a set of slides.

Medical students, for example, could gain surrogate experience by using interactive videodiscs to interview a "patient," make a diagnosis, and prescribe a therapy. This experience differs from the sort of structured problem found at the end of chapters, in that the student would have the opportunity to spot visual cues, elicit information essential to the diagnosis from an actual "patient," and determine the accuracy of those responses. As with computational microworlds, key variables could be manipulated here to encompass a range of situations against which various concepts and data could be tested.

Microworlds are beginning to appear in workplace situations both for training and task performance. Pilots accumulate substantial amounts of flying experience--

including first-hand knowledge of how to handle emergency situations--by interacting with elaborate, realistic simulations. Workers operating flexible manufacturing systems use microworlds to compare alternative scheduling patterns or to analyze possible causes of defective production. In postsecondary institutions, similar but simpler cognition enhancers can enhance training for occupations that require mastery of complex processes, as well as rapid and sophisticated performance.

Their users find microworlds extremely motivating. In fact, researchers are studying videogames, a popular example of artificial realities, to determine what makes them so intriguing. They hope to generalize this reinforcement to educational situations [Lepper & Malone, 1987]. Learning environments such as the Logo language, and other simulations now used in classrooms, are the beginnings of microworlds. For readers interested in further exploring this concept, the work of Smith, O'Shea, and Scanlon [1987] on the Alternate Reality Kit (ARK) illustrates a more advanced educational microworld, in which users can manipulate the laws of physics to experience how everyday activities (such as throwing a ball) consequently change.

In summary, new modalities for cognitive partnerships between users and intelligent tools are emerging. With this as background, how might emerging sophisticated functionalities in information technology be integrated in an instructional workstation?

The predictions in Part Two--after the References section--are condensed from research funded by NASA on emerging systems for knowledge creation, capture, transfer, and utilization [Dede, Sullivan, & Scace, 1988]. This material is intended both as a background reference to be consulted when questions arise about emerging

information technologies, and as information useful for understanding Part One. Readers not interested in the technical descriptions may wish to continue reading further on in Part One. However, those willing to skim the more technical information in Part Two may find the concepts introduced there useful in comprehending the ideas in this section.

Scenarios

A barrier to understanding the implications of advanced information technologies for instruction has been the diversity of capabilities emerging in a wide range of fields. To integrate the spectrum of themes discussed in Part Two a bit of foresight may be useful. The potential functionalities of an instructional workstation for postsecondary occupational training--should these advances actually be implemented--are presented below.

Much of the terminology here may be unfamiliar to readers who have not perused the more technical matter in Part Two, but a general sense of how such a device might operate should emerge. This illustrative scenario of the components and capabilities of an instructional workstation is a projection of probable technical feasibility only; whether such instructional devices will be developed will depend equally on economic, political and ideological factors.

> Sitting at an occupational training device in the year 2005, one is first struck by the most visible element of the workstation: the display. The monitor is a twenty-inch flat panel capable of presenting three-dimensional graphics, still and video images, and text in 4000 different colors (page 81). The screen resolution is close to four million pixels (2000 X 2000 lines of resolution); thus, it projects an image comparable to a high-quality printed page. Telecommunications links are provided primarily by fiber optic networks, with satellite linkages

a secondary system for long-haul communication (pages 80-83).

The workstation offers easy connectivity with other computers, peripherals, and telecommunications devices, since its architecture is designed on the basis of the OSI and ISDN standards and embedded microchips facilitate interconnectivity (pages 83-84). This instructional device can also run programs designed for other computers via emulation. The workstation is linked into several "information utilities"; these offer 1) integrated access to sources of data (newspapers, radio and television stations, journals and magazines, books, databases, electronic mail and computer conferencing networks) and 2) semi-automated tools for filtering, combining, manipulating, and sharing that information. (page 68).

A dual-erasable optical-disk system provides up to three gigabytes of secondary storage for mixed-object knowledge bases (pages 76-80). The system is equipped with a "megacard", which serves as both a means of security and a way to quickly upload or download information not captured on optical disk. The megacard is similar to a small plastic credit card and carries both the user's security profile in a protected mode and up to two megabytes of erasable memory for other types of information.

The workstation has limited voice recognition (user-specific, restricted vocabulary) and voice synthesis, coupled with a mouse or other input device and a keyboard (page 61). The User Interface Management System (UIMS) is designed to offer intelligent assistance (via embedded coaches and tutors) to novices, but also incorporates powerful command sets for experienced users (pages 54-56).

Interface functionalities available include direct manipulation, mimetic environments, limited "artificial realities," advanced input devices (such as the DataGlove™), and "microworlds" (pages 57-59). User productivity skills such as "linearizing" (performing several tasks while switching among them), task mapping, and "metacognition" ('thinking about thinking' to see patterns of suboptimal performance) are

empowered via "cognitive audit trails," "consciousness sensors," and intelligent, semi-autonomous agents (pages 59-61). The linking functionalities with other workstations on the network are designed to enhance the user's extrinsic motivation via cooperation, competition, and recognition. Intrinsic motivation is built through creating a learning environment which maximizes challenge, fantasy, curiosity, and control.

The hardware architecture is driven by a distributed parallel processor with 25 megabytes of local random access memory rated at 20 MIPS(pages 70-72). The parallel processor contains specialized embedded chips for image/graphic processing and voice recognition and can function as a linked distributed node on the network to which it is connected. Thus, it can provide expanded computing power for large-scale demands within its local-area network. This amount of power is capable of 100 LIPS (Logical Inferences Per Second) per MIP (Million Instructions Per Second) over an object knowledge base of 10^{10} objects, at a clock speed of 80 megahertz (page 43).

Such a system allows the user to interact with large knowledge bases, which contain the equivalent of universally quantifiable statements (e.g. "people of middle age are careful") rather than simple pieces of data, such as "Mr. Lee is 43 years of age" (pages 42-43). A Knowledge Base Management System (KBMS) handles deductive reasoning/search, inductive reasoning, explanation, knowledge refinement and validation, and automatic classification of knowledge in a manner transparent to the user. (Implications of using knowledge bases rather than data bases for occupational education are discussed later in this chapter.)

The workstation supports alternative knowledge-representation formats, such as "hypermedia" (page 44). This use of associational networks allows the implementation of sophisticated systems for conceptual exploration, retrieval, training, retention, group collaboration, customization, and revision (pages 45-50). Navigational aids help to minimize problems of disorientation and cognitive overhead, while

> difficulties with combinatorial explosion and collective communications are lessened through the use of instructional design strategies tailored to intelligent tutoring systems (pages 49-52).
>
> The workstation is linked as a node in a campus network via telecommunication lines and has both telephonic and electronic mail links to multiple industry and educational sites (pages 79-84). Attached is a "black box" which allows the connection of specialized manipulation or display devices. For example, the addition of an A/V camera enables the workstation to become a fully operational teleconferencing and documentation facility. Real-time digitization and storage of video data up to thirty frames per second is possible.
>
> By windowing the screen, the user can participate concurrently in a teleconference while manipulating information with other participants in a cooperative work environment (pages 64-70). Collaborative design (surfacing collective assumptions, resolving conflicts, developing shared models of a task), shared problem solving (text sharing, project management, collaborative authoring), and group decision support are enabled. WYSIWIS (What You See Is What I See) provides a common visual representation that can be manipulated by all participants.

Such a scenario may seem like something out of "science fiction" and, in terms of pedagogical and political barriers, its occurrence by the beginning of the next century is unlikely. However, the technical feasibility of such a workstation at affordable costs is quite real, should postsecondary occupational-training institutions collectively choose to implement advanced information technologies as rapidly as they are being developed.

While this scenario depicts the capabilities of an advanced instructional workstation, readers may have difficulties envisioning how a typical student could use such a device to acquire occupational skills. Accordingly,

a second scenario is presented below in which two learners interact using interconnected workstations:

> Karen sat down and punched her personalized megacard into an electronics diagnosis/repair training device. When sign-in was complete, the workstation acknowledged her readiness to begin Lesson Twelve: Teamed Correction of Malfunctioning Communications Sensor. She used the telecommunications conferencing mode to link to Phil, her partner in the exercise, who was sitting at a similar device in his dorm three buildings away.
>
> "What bad luck to get paired with this clown" she thought, noting a hung-over expression on his face and the rather garish pair of pajamas. "He probably spent last night partying and this morning sleeping instead of preparing for the lesson." A favorite saying of her instructor flitted through her mind, 'The effectiveness of computer-supported cooperative work can be severely limited by the team's weakest member.'
>
> "Let's begin," Karen said decisively. "I'll put on the DataArm to find and remove the faulty component. You use the HKB (hypermedia knowledge base) to locate the appropriate repair procedure." Without giving him time to reply, she brought up an AR (artificial reality) window depicting the interior of a TransStar communications groundstation receiver and began strapping on the DataArm. The monitor's meshing of computer graphics and video images presented a near-perfect simulation, although too-rapid movements on the screen could cause objects to blur slightly. Slowly, she "grasped" a microwrench with her "hand" on the screen and began to loosen the first fastener on the amplifier's cover. Tactile feedback from the DataArm to her hand completed the illusion, and she swore as she realized the bolt was rusty and would require care to remove without breaking.
>
> Meanwhile, Phil called up the HKB for Electronics Repair; on the screen, a multicolored, three-dimensional web of interconnections appeared and began slowly rotating. He groaned, just looking at the network made his eyes hurt. Since the screen resolution was excellent, he suspected

that last night's fourth margarita was the culprit.

Phil said slowly and distinctly, "Lesson Twelve," and a trail was highlighted in the network. He began "teleporting" among the nodes, simultaneously watching a small window in the upper left-hand corner of the screen which was beginning to fill with data from the diagnostic sensors on Karen's DataArm. Delay time for the workstation's response was negligible, even though megabytes of knowledge were being scanned, thanks to the optical disc secondary storage connected to his instructional device.

Traversing the network at the speed with which Karen was working was difficult, given his hangover, and Phil made several missteps. "Knowledge Base," Phil said slowly, "infer what the optical memory chip does to the three-dimensional quantum-well superlattice." The voice of his electronic coach suddenly responded,"You seem to be assuming a sensor flaw when the amplifier may be the problem." "Shut up!" Phil thought savagely, hitting the cut-off switch. He groaned when he visualized the cognitive audit trail of his actions feeding into the instructor's workstation; he could not terminate that incriminating record.

Mentally, he began phrasing an excuse to send the instructor via e-mail at the end of the lesson. Meanwhile, Karen was exasperatedly watching the window on her screen in which Phil's diagnostic responses should have been appearing. "He's hopeless," she thought. Her consciousness sensor interrupted with a warning: "Your blood pressure is rising rapidly; this could trigger a migraine headache." "Why," Karen said sadly, "couldn't I have lived in the age when students learned from textbooks "

A simulation this complex would require both elaborate hardware and sophisticated software, so as a standard instructional situation in the first decade of the twenty-first century its likelihood is low. However, this scenario does provide a means of visualizing where advances in intelligent instructional devices are leading.

For the reader interested in more detailed, annotated scenarios of sophisticated "learning while doing" task performance aids, an intelligent tutor, coach, and knowledge base are described in Dede [1988].

Timetable

To give a sense of the timing with which these diverse capabilities might emerge, Exhibit 2.1 estimates widespread commercial availability at prices comparable to advanced personal computer costs today. As discussed earlier, these projections have a significant margin of error, since technical forecasting is ultimately speculative rather than factual.

Some functionalities listed above are currently implemented on expensive engineering workstations; others are still in the experimental stage and have not become commercially available. Of course, whether these technical capabilities are rapidly implemented in postsecondary vocational, technical, and adult education will depend in part on whether buying collectives are formed which present sophisticated demands to vendors. Military and industrial training needs may spur the initial production of sophisticated instructional workstations, which then will gradually "trickle down" to educational institutions as prices fall and a widespread market forms for these functionalities.

Evolution

Over the next few years, some of these instructional capabilities will become robust and inexpensive enough to be used in postsecondary occupational education. Exhibit 2.2 indicates the relative likelihoods that, by 1995, the functionalities discussed above will be available on

EXHIBIT 2.1
AN APPROXIMATE TIMETABLE OF EMERGING TECHNOLOGIES FOR INSTRUCTION

Functionality	Uses	Time Frame
Cognitive audit trails	Support for finding patterns of suboptimal performance	Late 1980's
High-quality voice synthesis	Auditory natural-language output	Late 1980's
Hypermedia	Interlinking of diverse subject matter; easier conceptual exploration, training, collaboration	Late 1980's
Advanced manipulatory input devices	Mimetic learning which builds on real-world experience	Early 1990's
High-bandwidth fiber-optic networks	Massive real-time data exchange	Early 1990's
Synthesis of computers, telecommunications	Easy interconnection; realistic simulation	Early 1990's
Computer-supported cooperative work (collaborative design, collective problem solving, group-decision support), including WYSIWIS	Mastery of team task performance	Mid 1990's
Intelligent semi-autonomous agents	Support for user-defined independent actions	Mid 1990's
Optical-disk systems with multiple read/write and mixed media capabilities	Support of large data and knowledge bases; very cheap secondary storage; facilitation of artificial realities	Mid 1990's

EXHIBIT 2.1 CONCLUDED

Sophisticated User Interface Management Systems	Easier development of instructional applications; reduced time for novices to master a program	Mid 1990's
Standardization of computer and telecommunications protocols	Easy connectivity, compatibility; lower costs	Mid 1990's
Consciousness sensors	Monitoring of mood, state of mind	Late 1990's
Current mainframe performance levels on microcomputers	Sufficient power for advanced functionalities	Late 1990's
High-resolution color monitors; real-time animation of 3-D graphics	Easy reading of text; vivid simulation of reality	Late 1990's
Information utilities	Access to integrated sources of data and tools for assimilation	Late 1990's
Knowledge processing and Knowledge Base Management Systems	Goal-oriented, context-specific mastery of concepts and skills	Late 1990's
Microworlds	Experience in applying theoretical information in practical situations	Late 1990's
User-specific, limited-vocabulary voice recognition	Restricted natural-language input	Late 1990's
Artificial Realities	Intensely motivating simulation and experience	Year 2000+
Intelligent tutors and coaches for restricted domains	Models of embedded expertise for greater individualization	Year 2000+

EXHIBIT 2.2

EVOLUTION OF INSTRUCTIONAL TECHNOLOGIES BY 1995

Highly Probable/Almost Certain

- High-quality voice synthesis
- Advanced manipulatory input devices
- Cognitive audit trails
- Hypermedia
- Synthesis of computers, telecommunications

Reasonably Probable

- High bandwidth fiber-optic networks
- Standardization of computer and telecommunications protocols
- Optical disc systems with multiple read/write and mixed-media capabilities
- Sophisticated User Interface Management Systems
- Complex simulations
- Computer-supported cooperative work

Conceivable/Uncertain

- High-resolution color monitors with 3-D real-time animated graphics
- User-specific, limited-vocabulary voice recognition
- Microworlds
- Intelligent tutors and coaches for practice sessions on skills already taught
- Consciousness sensors
- Intelligent semi-autonomous agents
- Knowledge processing
- Current mainframe performance levels on microcomputers
- Information utilities

Unlikely

- Multiple-speaker, natural-language voice recognition
- Intelligent tutors and coaches for stand-alone instruction in restricted domains
- Artificial realities

affordable microcomputer systems and widely used in occupational education.

The rapidity with which intelligent instructional devices create a new paradigm for postsecondary occupational education depends on several factors:

- how quickly the workplace changes due to technological advances and global competition
- how many resources society commits to purchasing hardware, developing courseware, and retraining instructors
- how much resistance educators mount to changing their professional skills and organizational structures

Heuristics for speeding this evolution are presented in Chapter 5, **Planning Guidelines for Utilizing Emerging Instructional Technologies**. The rate of change will likely be determined much more by psychological and political constraints than by technological or economic limits.

Summary

As the scenarios and timetables indicate, by the early part of the next century instructional technologies for occupational education could be very different than the devices used today. This is not a long period of time; considering that hand-held calculators hit the market less than 20 years ago. Current decisions about the usage of instructional technology in occupational education need to emphasize flexibility and upgradability, so that as these different functionalities mature, a smooth path of integration and evolution is available. By 1995, instructional devices could be much more powerful than current occupational training workstations; present purchasing decisions and curriculum development are

already shaping that future. Strategic planning to guide this transformation is essential.

This type of planning will require overcoming two myths in instructional technology [Dede, 1987]. The Myth of Power states that novices need less powerful devices than expert users. This chapter argues the opposite: rapid computational speed and large amounts of memory are required to support the self-explicating interfaces, multiple mental models, and alternative knowledge representations helpful to beginners. Experienced users actually need less power to run complex, but non-explanatory versions of the same applications. The Apple IIGS™, the IBM System 2 Model 25™, and similar machines from other vendors are too limited in processor speed to support the next generation of advanced learning environments; but these machines are being sold to educators to create the "classroom of the future!"

The Myth of Consolidation states that the wave of innovation in instructional technology is over: we now know what computers can do for students, and based on this summative evaluation we can restrict our educational investments to more of the same machines, software, and teacher training. This chapter argues the opposite: more powerful tools are now emerging; attempts to judge how instructional devices can improve learning have been premature, and the wave of technological change in educational institutions has not yet crested.

Implications for Occupational Education

The two most common errors in technology assessment are overestimating the speed of diffusion of an innovation, while underestimating its eventual consequences and side-effects. These devices may arrive more slowly than expected, since the primary limits on technological diffusion are social, economic, and political, but their

impact on the traditional instructional paradigm will be profound. To stimulate the reader's ideas about the consequences of these advanced workstations for postsecondary vocational, technical, and adult education, some potential effects of the widespread, long-term usage of cognition enhancers are developed below [Dede, 1987].

--Partnerships between people and cognition enhancers involve skills such as creativity, flexibility, decision-making given incomplete data, complex pattern recognition, information evaluation/synthesis, and holistic thinking. Such higher-order mental attributes might contribute to a new definition of human intelligence, as the burden of basic cognitive skills increasingly shifts to the intelligent tool. Promoting student mastery of lower-level skills will be like grooming John Henry to compete with the steam engine!

--Students will still need fundamental descriptive and procedural knowledge--one cannot master higher-order skills without a foundation of lower-order concepts and processes--but the goal of teaching basics would shift from ensuring performance fluency to providing a cognitive underpinning for sophisticated problem-recognition and unusual problem-solving. Methods of educational assessment would evolve from charting mastery of descriptive knowledge to evaluating attainment of higher-order skills. Fortunately, cognition enhancers can aid in both collecting the detailed individual data necessary, and empowering more sophisticated empirical educational research.

--"Learning while doing" should become a more significant component of education, as combined computer and telecommunications technologies allow delivery of instructional services in a decentralized manner. To allow credit for occupational

accomplishments, workplace tools may include intelligent devices that act as job-performance aids, while simultaneously collecting a cognitive audit trail of user-skill improvements, and creating increasingly informal systems of credentialization. As the evolution of information technologies creates a knowledge-based economy, occupational roles will alter rapidly with adults becoming a major clientele of educational institutions [Office of Technology Assessment, 1984].

--Widespread use of cognition enhancers will facilitate the participation of every person associated with the educational process--learner, teacher, administrator, employer, or parent--in shaping instructional outcomes. Society's five primary educational agents (schools, family, community, media, workplace) could act in more coordinated fashion to shape the learning environments of individuals through the use of interlinked "educational information utilities," which supply access to a variety of data, courseware, tools, and training [Dede, 1985b].

--Productivity gains from a mature, technology-intensive educational approach could enable smaller class sizes for group instructions within a higher overall ratio of students to teachers, via supplementary use of intelligent technologies and non-school instructional agents [Melmed, 1986]. Teacher salaries would be higher, while the total educational workforce should increase due to a wider range of clients. Given equivalent expenditures, instructional outcomes would be significantly improved.

--In time, the effects of intelligent technologies on cognitive style, personality, and social skills may be profound [Turkle, 1984]. Both television and the computer have demonstrated the capability to shape the attributes of youngsters immersed in their usage. The deliberate tailoring of individualized, information-intensive environments could produce similar effects on future generations. For example, a technology-intensive model could incorporate interactive learning situations designed to build the affective skills of cooperation, compromise, and group decision-making essential in a knowledge-based economy.

--Educational equity should increase through the power of intelligent systems to individualize instruction. Because the economic strength of a knowledge-based democracy is dependent on universally excellent performance by workers and citizens, each member of society would have a marked self-interest in promoting optimal educational achievement by all learners.

Behind these potential shifts is a new paradigm for using information technologies. Originally, computers were seen as number-crunching machines; gradually, their data-processing capabilities were recognized. Now, the strengths of integrated computer and telecommunications devices for all forms of individual and group symbolic manipulation is being explored.

The conceptualization of information technologies as symbolic-manipulation devices is spurring research into how data and information can be converted to knowledge and wisdom [Dede, Sullivan, & Scace, 1988]. Common usage of these terms conveys a sense of increasing complexity and utility, but a rigorous delineation of their subtle

differences is much more difficult. As a simplified categorical system for the purposes of this chapter, "data" will be defined as input gathered through the senses; and "information" as integrated data that denotes a significant change in the environment. (Anthropologist Gregory Bateson [1975] defined "information" as "any difference that makes a difference.") Information is converted to "knowledge" by interconnection with known concepts and skills in achieving a goal. Knowledge has an attribute of purpose, implying the direction of an intelligent agent (human or computational) in transforming information into knowledge. "Wisdom," then, is knowledge about knowledge, or "meta-knowledge".

For a software programmer, the existence of a new primitive procedure in the programming language would be data; an understanding of what new functions it adds to the language would be information; comprehension of <u>how</u> to use the procedure in coding would be knowledge; while mastery of <u>when</u> to use it, taking into account its effects on overall programming style, would constitute wisdom. Comparable analogies can be constructed for other types of task performance taught in occupational education.

Past generations of information systems have used advances in hardware and software to increase the amount of data available, on the assumption that individual and institutional wisdom would thereby increase. In practice, however, large amounts of data tend to overwhelm the user, who finds it difficult, first, to decide which information is important, then to interconnect new information into existing knowledge, and finally to recognize overall patterns of meta-knowledge. Future generations of information systems--and instructional systems--will instead use increases in power to deliver environmentally

meaningful, contextually targeted, interconnected data ("knowledge").

Conclusion

The potential implications for civilization of intelligent educational environments could be profound. The next generation of information technologies could become history's first "knowledge medium": humanity's conscious mechanism for tailoring its cognitive evolution [Stefik, 1986]. For example, in the final chapter of his book, The Selfish Gene, Richard Dawkins [1976] suggests that ideas (he calls them "memes") are like genes. This conjures up myriad analogies: meme pools, mimetic drift, mutation, displacement, and even recombinant memes. Education would be a crucial component in society's attempt to increase knowledge and wisdom through intelligent tools that aid in the collecting, filtering, modeling, and sharing of massive amounts of data and information.

If this vision holds true, over the next generation civilization may be profoundly shaped by two types of scientific advances: genetic and mimetic manipulation. These will profoundly alter the definition of "instructional effectiveness," as shifts occur in the knowledge, skills, and values needed to be a worker, citizen, and self-actualized human being [Dede & Freiberg, 1986]. In turn, postsecondary vocational, technical, and adult education must change to prepare its clients for this dynamic, but uncertain future.

The fundamental question for institutional strategic planning is always, "how may our mission change in the mid-range future?" For example, in the early part of this century, the railroad industry carefully projected long-range demand and likely technical advances: the amount of

freight to be carried, the speed of trains, the necessary miles of track. Those predictions went askew because the planners neglected the advent of the automobile and the airplane. Railroad people thought they were in the railroad business, when actually they were in the transportation business. A broader conception of their mission might have reshaped today's transportation industry structure. Given these advances in information technology and their consequences for society, how may our total mission change?

References

Abraham, Eitan, Seaton, Colin, and Smith, S. Desmond. (1983) The Optical Computer. Scientific American 248, 2 (February, 1983), 85-93.

Anderson, John R. (1983) The Architecture of Cognition. Cambridge, MA: Harvard University Press.

Bateson, Gregory. (1975) Steps to an Ecology of Mind. New York: Ballantine.

Bezold, C., and Olson, R. (1986) The Information Millennium: Alternative Futures. Alexandria, VA: Institute For Alternative Futures.

Blair, D.C. and Maron, M.E. (1985) An Evaluation of Retrieval Effectiveness for a Full-Text Document-Retrieval System. Communications of the ACM 28, 3 (March, 1985), 289-299.

Borning, A. (1981) The Programming Language Aspects of ThingLab, a Constraint Oriented Simulation Laboratory. ACM Transactions on Programming Languages and Systems 3, 4, 353-387.

Brachman, Ronald J., and Levesque, Hector J., Eds. (1985) Readings in Knowledge Representation. Los Altos, CA: Morgan Kaufmann.

Brodie, Michael L. (1986) Large-Scale Knowledge Based Systems: Concluding Remarks and Technological Challenges. Michael Brodie & John Mylopoulos, Eds., On Knowledge Base Management Systems: Integrating Artificial Intelligence and Database Technologies. New York: Springer-Verlag.

Brown, John Seely. (1985) Process Versus Product: A Perspective on Tools for Communal and Informal Electronic Learning. Journal of Educational Computing Research 1, 179-202.

Brown, John Seely, and Moskovitz, Gary. (1985) AI: Windows of Opportunity in Office Automation. Palo Alto, CA: Xerox PARC.

Brown, John Seely. (1986) From Cognitive to Social Ergonomics. In Donald A. Norman and Stephen W. Draper (Eds.), User-Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum.

Burke, Gerald, and Rumberger, Russell W., Eds. (1987) The Future Impact of Technology on Work and Education. New York: Falmer Press.

Burton, Richard R. (1986) The Environment Module of Intelligent Tutoring Systems. Palo Alto, CA: Xerox Palo Alto Research Center.

Card, S.K., Moran, T.P., and Newell, A. (1983) The Psychology of Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum.

Card, Stuart K., and Henderson, D. Austin. (1987) A Multiple, Virtual-Workspace Interface to Support User Task Switching. Proceedings of CHI+GI 1987. New York: ACM.

Carroll, John M. and McKendree, Jean. (1987) Interface Design Issues for Advice-Giving Expert Systems. Communications of the ACM 30, 1 (January, 1987), 14-31.

Clancey, William J. (1987) Knowledge-Based Tutoring: The Guidon Program. Cambridge, MA: MIT Press.

Coates, Joseph F. (1977) Aspects of Innovation: Public Policy Issues in Telecommunications Development. Telecommunications Policy 1, 3, 11-13.

Conklin, Jeff, and Richter, Charles. (1985) Support for Exploratory Design. Austin, TX: MCC Technical Report STP-117-85, Microelectronics and Computer Technology Consortium.

Conklin, Jeff. (1986) A Theory and Tool for Coordination of Design Conversations. Austin, TX: Technical Report STP-236-86, MCC.

Conklin, Jeff. (1987) Hypertext: An Introduction and Survey. Computer 20, 9, 17-41.

Corkill, D.D., and Lesser, V.R. (1983) The Use of Meta-Level Control for Coordination in A Distributed Problem Solving Network. Proceedings of the International Joint Conference on Artificial Intelligence. Los Altos, CA: Morgan Kauffman.

Cypher, Allen. (1987) The Structure of Users' Activities. Donald A. Norman and Stephen W. Draper (Eds.), User-Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum.

Danzinger, James N. and Kraemer, Kenneth L. (1986) People and Computers: The Impacts of Computing on End Users in Organizations. New York: Columbia University Press.

Dawkins, Richard. (1976) The Selfish Gene. New York: Oxford University Press.

Dede, Christopher J. (1985a) New Information Technologies, the Knowledge Based Economy, and Education. Educational Media International 15, 2 (Summer, 1985), 2-9.

Dede, Christopher J. (1985b) Assessing the Potential of Educational Information Utilities. Library Hi Tech 3, 4 (Winter, 1985), 115-119.

Dede, Christopher J. (1986) A Review and Synthesis of Recent Research in Intelligent Computer-Assisted Instruction. International Journal of Man-Machine Studies 24, 4, 329-353.

Dede, Christopher, and Freiberg, Jerome. (1986) The Long Term Evolution of Effective Schools. Educational Forum 51, 1 (Fall, 1986), 65-80.

Dede, Christopher J. (1987) Empowering Environments, Hypermedia, and Microworlds. The Computing Teacher 15, 3 (November, 1987), 20-25.

Dede, Christopher, Sullivan, Tim, and Scace, Jacque. (1988) Forces Influencing the Evolution of Electronic Documentation Systems. Houston, TX: Johnson Space Center, NASA.

Dede, Christopher J. (1988) Artificial Intelligence Applications to High Technology Training. Journal of Educational Communications and Technology (in press).

Dede, Christopher J., and Swigger, Kathleen M. (1988) The Evolution of Instructional Design Principles for Intelligent Computer Assisted Instruction. Journal of Instructional Design (in press).

diSessa, Andrea A. (1985) A Principled Design for an Integrated Computational Environment. Human-Computer Interaction 1, 1, 1-57.

diSessa, Andrea A. (1986) Notes on the Future of Programming: Breaking the Utility Barrier. In Donald A. Norman and Stephen W. Draper (Eds.), User Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum.

Donahue, James, and Widom, Jennifer. (1986) Whiteboards: A Graphical Database Tool. ACM Transactions on Office Information Systems 4, 1, 24-41.

Dongarra, Jack C., Ed. (1987) Experimental Parallel Computing Architectures. Amsterdam: Elsevier Science Publishing Company, Inc.

Drexler, K. Eric. (1986) Engines of Creation. New York: Doubleday.

Fairchild, Kim F. (1984) Computer Generated Synthesized Imagery. Minneapolis, MN: Computer Science Department, University of Minnesota.

Fairchild, Kim F. and Gullichsen, Eric. (1986) From Modern Alchemy to a New Renaissance. Austin, TX: MCC Technical Report HI-400-86, Microelectronics and Computer Technology Corporation.

Foley, James D. (1987) Interfaces for Advanced Computing. Scientific American 257,4 (October, 1987), 126-135.

Garrett, L. Nancy, Smith, Karen, and Meyrowitz, Norman. (1986) Intermedia: Issues, Strategies, and Tactics in the Design of a Hypermedia Document System. Proceedings of the 1986 Conference on Computer Supported Cooperative Work. Austin, TX: Microelectronics and Computer Technology Corporation.

Gentner, D., and Stevens, A. (1983) Mental Models. Hillsdale, NJ: Lawrence Erlbaum.

Gibson, William. (1984) Neuromancer. New York: Ace.

Halasz, Frank G., Moran, Thomas P., and Trigg, Randall H. (1987) NoteCards in a Nutshell. Proceedings of CHI+GI 1987. New York: ACM.

Hillis, W. Daniel, and Steele, Guy L., Jr. (1986) Data Parallel Algorithms. Communications of the ACM 29, 12 (December, 1986), 1170-1183.

Hillis, W. Daniel. (1987) The Connection Machine. Scientific American 256, 6 (June, 1987), 108-115.

Hopfield, J.J., and Tank, D.W. (1986) Computing with Neural Circuits: A Model. Science 233, 4764 (August 8, 1986), 625-633.

Hutcheson, L.D. (1986) Design Criteria For AlGaAs/GaAs Integrated Optoelectronic Designs. Integrated Optical Circuit Engineering IV. Cambridge, MA: The International Society for Optical Engineering.

Hutchins, Edwin L., Hollan, James D., and Norman, Donald A. (1987) Direct Manipulation Interfaces. Donald A. Norman and Stephen W. Draper (Eds.), User-Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum.

Jonassen, David H. (1986) Hypertext Principles for Text and Courseware Design. Educational Psychologist 21, 4 (Fall, 1986), 269-292.

Kahn, Robert E. (1987) Networks for Advanced Computing. Scientific American 257, 4 (October, 1987), 136-143.

Kay, P. and Powell, P., Eds. (1984) Future Information Technology-Telecommunications. Washington DC: U.S. Department of Commerce.

Kraemer, Kenneth L., and King, John Leslie. (1986) Computer-Based Systems for Cooperative Work and Group Decision Making: Status of Use and Problems in Development. Proceedings of the 1986 Conference on Computer Supported Cooperative Work. Austin, TX: Microelectronics and Computer Technology Corporation.

Kraut, Robert E., Galegher, Jolene, and Egido, Carmen. (1986) Relationships and Tasks in Scientific Research Collaboration. Proceedings of the 1986 Conference on Computer Supported Cooperative Work. Austin, TX: Microelectronics and Computer Technology Corporation.

Lantz, Keith A. (1986) An Experiment in Integrated MultiMedia Conferencing. Proceedings of the 1986 Conference on Computer Supported Cooperative Work. Austin, TX: Microelectronics and Computer Technology Corporation.

Laurel, Brenda K. (1986) Interface as Mimesis. Donald A. Norman and Stephen W. Draper (Eds.), User-Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum.

Lenat, Doug, Prakash, Mayank, and Shepherd, Mary. (1986) CYC: Using Common Sense Knowledge to Overcome Brittleness and Knowledge Acquisition Bottlenecks. AI Magazine 6, 4, 65-85.

Lewis, Matthew W., Milson, Robert, and Anderson, John R. (1987) The TEACHER'S APPRENTICE: Designing an Intelligent Authoring System for High School Mathematics. Greg P. Kearsley (Ed.), Artificial Intelligence and Instruction: Applications and Methods. New York: Addison-Wesley.

Lowe, David G. (1985) Cooperative Structuring of Information: The Representation of Reasoning and Debate. International Journal of Man-Machine Studies 23, 97-111.

Malone, Thomas W. and Lepper, Mark R. (1985) Making Learning Fun: A Taxonomy of Intrinsic Motivations for Learning. R.E. Snow and M.J. Farr (Eds.), Aptitude, Learning, and Instruction: III. Conative and Affective Process Analysis. Hillsdale, NJ: Lawrence Erlbaum.

Malone, Thomas W. and Smith, Stephen A. (1986) Modeling the Performance of Organizational Structures. Cambridge, MA: Center for Information Systems Research, Sloan School of Management, MIT.

Malone, Thomas W. (1986) Computer Support for Organizations: Toward an Organizational Science. John M. Carroll (Ed.), Interfacing Thought: Cognitive Aspects of Human-Computer Interaction. Cambridge, MA: MIT Press.

Malone, Thomas W., Grant, Kenneth R., Lai, Kum-Yew, Rao, Ramana, and Rosenblitt, David. (1986) Semi-Structured Messages Are Surprisingly Useful for Computer-Supported Coordination. Proceedings of the 1986 Conference on Computer Supported Cooperative Work. Austin, TX: Microelectronics and Computer Technology Corporation.

Malone, Thomas W., Grant, Kenneth R., Turbak, Franklyn A., Brobst, Stephen A., and Cohen, Michael D. (1987) Intelligent Information Sharing Systems. Communications of the ACM 30, 5, 390-402.

Marshall, Ray. (1987) Education, Technology, and the Texas Economy: 1987-1989. Austin, Texas: University of Texas.

McAlear, James H., and Wehrung, John M. (1984) The Biochip: Now, 2000 A.D., and Beyond. IBM 15 (August, 1984), 51-56.

Meindl, James D. (1987) Chips for Advanced Computing. Scientific American 257, 4 (October, 1987), 78-88.

Melmed, Arthur. (1986) The Technology of American Education: Problem and Opportunity. T.H.E. Journal 14, 2, 77-81.

Miller, James R. (1986) Human-Computer Interaction and Intelligent Tutoring Systems. Austin, TX: MCC Technical Report HI-086-17, Microelectronics and Computer Technology Consortium.

Mylopoulos J. (1986) On Knowledge Base Management Systems. Michael L. Brodie and John Mylopoulos, Eds, On Knowledge Base Management Systems: Integrating Artificial Intelligence and Database Technologies. New York: Springer-Verlag.

Norman, Donald A. (1987) Cognitive Engineering--Cognitive Science. John M. Carroll (Ed.), Interfacing Thought: Cognitive Aspects of Human-Computer Interaction. Cambridge, MA: MIT Press.

Office of Technology Assessment, U.S. Congress. (1984) Computerized Manufacturing Automation: Education, Employment, and the Workplace. Washington, D.C.: USGPO.

Office of Technology Assessment, U.S. Congress. (1985) Information Technology R & D: Critical Trends and Issues. Washington, DC: U. S. Government Printing Office.

Pea, Roy D. (1987) Human-Machine Symbiosis: Exploring Hypermedia as New Cognitive and Cultural Technologies. Proceedings of the International Symposium on Computers, Cognition, and Epistemology. Denmark: University of Aarhus.

Perrault, C. Raymond, and Grosz, Barbara J. (1986) Natural-Language Interfaces. J.F. Traub (Ed.), Annual Review of Computer Science, Volume 1. Palo Alto, CA: Annual Reviews.

Reichman, Rachel. (1986) Communication Paradigms for a Window System. Donald A. Norman and Stephen W. Draper (Eds.), User-Centered System Design: New Perspectives on Human-Computer Interaction. Hillsdale, NJ: Lawrence Erlbaum.

Rittel, Horst, and Webber, Melvin. (1973) Dilemmas in a General Theory of Planning. Policy Sciences 4, 111-127.

Rouse, William B., and Morris, Nancy M. (1986) On Looking into the Black Box: Prospects and Limits in the Search for Mental Models. Psychological Bulletin 100, 3 (March, 1986), 324-355.

Russell, Daniel M., Moran, Thomas P., and Jordan, Daniel S. (1987) The Instructional Design Environment. J. Psotka, L.D. Massey, and S.A. Mutter (Eds.), Intelligent Tutoring Systems: Lessons Learned. Hillsdale, NJ: Lawrence Erlbaum.

Sheil, B.A. (1982) Coping with Complexity. Richard A. Kasschau, Roy Lachman, and Kenneth R. Laughery (Eds.), Information Technology and Psychology: Prospects for the Future. New York: Praeger.

Shneiderman, Ben. (1983) Direct Manipulation: A Step Beyond Programming Languages. IEEE Computer 16, 8, 57-69.

Shneiderman, Ben. (1987) User Interface Design and Evaluation for an Electronic Encyclopedia. Proceedings of the Second International Conference on Human-Computer Interaction. New York: North-Holland.

Smith, Randall B. (1987) Experiences with the Alternate Reality Kit: An Example of the Tension Between Literalism and Magic. Proceedings of CHI+GI 1987. New York: ACM.

Spenner, Kenneth. (1985) The Upgrading and Downgrading of Occupations: Issues, Evidence, and the Implications for Education. Review of Educational Research 55 (Summer, 1985), 125-154.

Stefik, Mark. The Next Knowledge Medium. The AI Magazine 7, 1, 34-46.

Stefik, Mark, Foster, Gregg, Bobrow, Daniel G., Kahn, Kenneth, Lanning, Stan, and Suchman, Lucy. (1987) Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings. Communications of the ACM 30, 1, 32-47.

Suchman, Lucy A. (1985) Plans and Situated Actions: the Problem of Human-Machine Communication. Palo Alto, CA: Technical Report ISL-6, Xerox Palo Alto Research Center.

Tsunoda, Yoshito. (1985) Present Status And Future Trends In Erasable Optical Memories. Proceedings of the Laser and Electro Optics Society. Washington, DC: Laser and Electro Optics Society.

Turkle, Sherry. (1984) The Second Self: Computers and the Human Spirit. New York: Simon & Schuster.

Weyer, Stephen A. and Borning, Alan H. (1985) A Prototype Electronic Encyclopedia. ACM Transactions on Office Systems 3, 1, 63-88.

Wilson, Kathleen S. (1987) The Palenque Optical Disc Prototype. New York: Technical Report No. 44, Bank Street College of Education.

Woods, William A. (1975) What's in a Link: Foundations for Semantic Networks. Brachman, Ronald J. and Levesque, Hector J., Eds. Readings in Knowledge Representation. Los Altos, CA: Morgan Kaufmann.

Yankelovitch, N., Meyrowitz, N., and van Dam, A. (1985) Reading and Writing the Electronic Book. Computer 18, 10 (October, 1985), 15-30.

PART TWO: The Evolution of the Information Technologies

As discussed earlier, these predictions are condensed from research funded by NASA on emerging systems for knowledge creation, capture, transfer, and utilization [Dede, Sullivan, & Scace, 1988]. The material in this section can be consulted when questions about emerging information technologies arise. The information should also prove useful in understanding Part One.

The emphasis here is on functionality, with forecasts taking into account advances in hardware capabilities, as well as the emergence of software applications that take advantage of increased power and declining cost. The barriers and limits posed in developing software should not be underestimated; in many cases they are the basis for conservative estimates of when a new technology will likely be available.

For example, the Intel 80486™ microprocessor is scheduled for release in 1990. The successor to the 80386--the core of the IBM PS/2™ machines and their compatibles --will have about eight times the speed and five times the number of transistors. (In fact, the number of "secondary" transistors on the 80486 dedicated to telecommunications linkages is comparable to the total number of transistors on the 80386.) However, the development of mature software for the 80386 may well take until the mid-1990's, so the full capabilities of the more powerful 80486 generation of hardware are not likely to be realized until significantly later.

Functionalities which are emerging as the result of work in computer science, linguistics, cognitive science, philosophy, education, and psychology are briefly discussed below. These are divided into three themes: knowledge representation, user interfaces, and computer-

supported cooperative work. Finally, the hardware evolution that will support the implementation of these capabilities is summarized.

Knowledge Representation

The demand for more sophisticated methods of representing data, information, and knowledge within an information system environment has resulted in new approaches that embody concepts of Artificial Intelligence (AI). One field of endeavor, for instance has centered on integrating knowledge processing with the more mature technology of Data Base Management Systems (DBMS). A second strategy, discussed later in this section, hinges on finding more powerful ways of representing knowledge within the computer.

Developing Knowledge Based Management Systems (KBMS)

DBMS technology has its roots in the 1960's practice of developing data-processing software programs (or applications) within an organization. This was also known as "programming in the small." Typically, when confronted with problems "A,B,C" and data (highly structured information that could be contained and manipulated in a fixed-field type architecture) associated with each individual problem, the conventional method of handling this situation was to develop unique automated programs "1,2,3" for solving each specific problem.

PROBLEM "A" + DATA + PROGRAM 1 = OUTPUT 1
PROBLEM "B" + DATA + PROGRAM 2 = OUTPUT 2
PROBLEM "C" + DATA + PROGRAM 3 = OUTPUT 3 .....

Over time, the result was multiple programs having no design consistency, containing redundant and often inconsistent data, or generating mutually incompatible output. No easy way could be found to integrate these various programs. They had been developed in a vacuum

with little thought given to overlap, and they were built using inconsistent methods and tools.

The introduction of DBMS technology in the 1970's improved this situation. DBMSs provided a common set of data-processing tools and architecture with which to build data applications; a query language which made information retrieval easier and far more flexible; along with the capability to use data in a variety of programs without redundancy. For example, information on customer orders could be linked to inventory records via data transfer in a standard, generalized format. The results were integrity and consistency of data between differing programs, easier accessibility, and a faster development lifecycle for applications.

However, DBMS technology did not significantly affect the problem of capturing different, more abstract information formats, since it was still relegated to managing highly structured "data." Modeling real-world phenomena requires more than just columns and rows of alphanumeric charter strings. The late 1970's to mid-1980's saw the evolution of office automation and the shift from structuring "data" to managing "information." Much of this evolution resulted from the development of such devices as the personal computer and the dedicated word processor, since these systems began capturing the next genre of information, text, via a magnetic medium. (Text differs from data in that its most natural form is sentences and paragraphs contained in a document, as opposed to the columns and rows in a matrix.)

Currently, information processing and office automation are oriented towards innovations such as desktop publishing (merging text with graphics), facsimile systems for transmitting documents as an image, and full-text retrieval (indexing complete documents on a word-by-

word basis, while allowing for complex queries of words and phases with Boolean and proximity logic). However, each of these systems requires a unique system and file structure of its own.

When organizations tried implementing a variety of solutions to the management of text, the "data processing" problems of the early 1970's manifested themselves in slightly different form. Letters to purchasers confirming orders might be stored in a text format incapable of being transferred, either to customer profiles (graphs) compiled by marketing or to customer-inventory database records kept to trigger sales calls. The dissemination of multiple-applications programs, which employ different text management solutions, has resulted in little integration, either between the various text management systems or with existing DBMS applications already in the workplace.

The mid-1980's saw the emergence of text-management strategies designed to address this lack of integration between the various text systems and applications that proliferated. These systems are still evolving, and provide benefits similar to DBMS technology, by allowing "information" to be managed with common automation tools, while facilitating linkage with existing DBMS systems. A likely next step will be to integrate the management of images and graphics in the database.

A similar evolution is now taking place in the development of "expert" systems and knowledge-based management systems. While a DBMS represents and manages facts, a knowledge base describes and operates on classes of objects [Brachman & Levesque, 1986]. A knowledge base contains the equivalent of universally quantifiable statements (e.g. "people of middle age are careful"), while a database contains the equivalent of basic

assertions (e.g., "Mr. Lee's age is 43 years"). Combining DBMS functional strengths (such as data modeling, query/browsing, concurrency, error recovery, security, definition, maintenance, search and update optimization) with the more advanced capabilities of a knowledge base (knowledge-representation schemes, deductive reasoning/search, inductive reasoning, explanation, knowledge refinement and validation, and automatic classification of knowledge) is the goal of present KBMS research.

Evolving from "data processing" to "knowledge processing" implies 1) a richer, fuller description of the knowledge domain and the objects within it, and 2) the ability of the system to make calculated inferences about the relationships of the domain objects. DBMS systems, for instance, have only limited ability to capture the descriptive characteristics of "ownership," "causality," "dimension," and "time". Yet these abstract notions are critical to the process of describing a knowledge domain. KBMS technology would provide the capability to handle abstractions of this sort within the context of a knowledge base.

Current DBMS technology manages "data" as isomorphic representations of domain objects, described in the context of alphabetical or numeric character strings contained in a two- dimensional matrix of data fields represented by rows and columns. Additional relationships can then be created by defining logical relationships to link matrices together. With current database technology, however, the entity described by various descriptive data elements is not managed as a coherent object with certain characteristics (i.e.,"knowledge"); rather, each piece of data is managed individually.

Commercially available KBMS technology is presently in the early stages of development. A variety of challenges must be understood and overcome before such systems will emerge from the laboratory. Critical issues include performance tradeoffs between flexibility and efficiency, the need for better modeling languages and methodologies for knowledge acquisition, storage and knowledge capacity, and processing for large scale knowledge bases from both a hardware and software perspective.

KBMS and DBMS both employ the "search" function, though in distinctive ways. KBMS uses an inference search; DBMS, query evaluation. Inferencing is more flexible, both in terms of expression and in the addition of new knowledge with no impact on existing representations. DBMS query evaluation is more rigid in terms of expression and in the class of data against which searches can be run. However, this approach is computationally more efficient and can handle substantially greater amounts of data in a given storage capacity. The size of knowledge bases, in comparison to DBMS, tends to be small; and the processing speed of the search, slow.

KBMS storage capacity is measured in objects (knowledge chunks composed of rules, frames, facts); current KBMS technology supports knowledge bases of about 10^3 objects. While there are KBMSs capable of storing 10^6 objects under development [Brodie, 1986], large-scale applications will require capacities which approach the range of present DBMS technology (or approximately 10^{10} objects). Unlike the DBMS, which relies on secondary storage, a KBMS typically relies on main-memory storage. Their adoption will drive the need for large random access memories, while increases in KBMS storage capacities will force the development of better means of knowledge base maintenance. This entails verifying knowledge,

maintaining the integrity of relationships between knowledge chunks in the face of updates, and maintaining indices.

Knowledge processing performance is measured in LIPS (Logical Inferences Per Second), a measure of inference processing, where 1 LIP is roughly equal to 100 to 1000 instructions per second per MIP of hardware. Current KBMS technology can support a rate of 10^2 LIPS per MIP over 10^3 object knowledge bases. In equivalent terms, DBMS technology now supports 10-30 LIPS per MIP over 10^{12} object databases. KBMSs should at least be capable of approaching the processing performance of DBMSs for large object databases [Mylopoulos, 1986].

In summary, the integration between current information technologies (such as DBMS, CAD, Text Management, and Image Management) and emerging artificial intelligence technologies (such as expert systems, natural language, and sophisticated knowledge representation schemes) is well underway. The result will ultimately be a more comprehensive means of providing highly efficient management of large, shared knowledge bases for knowledge-directed systems. These Knowledge Base Management Systems are emerging in a variety of forms more or less coupled with DBMS technology, depending on function and design. The ultimate capabilities of KBMSs include:

- multiple knowledge-representation schemes
- multiple knowledge-directed applications
- context-free information and context-sensitive advice
- new means of automated organization of knowledge

New Types of Knowledge Representation

A second theme within research on knowledge systems concerns creating new representational formats. A fundamental aspect of any information system is the way it

represents knowledge. Symbols, for instance, "re-present" reality, and the properties of any form of communication are shaped by the attributes of its symbolic substrate. For example, sometimes "a picture is worth a thousand words," because pictorial representations are better suited to the needs of particular knowledge-transfer situations.

Descriptions based solely on text can be cumbersome, compared to multi-media formats which allow easy incorporation of graphics, images, and animation. Text presents information in a sequential manner, but a person using an information system frequently needs access to knowledge linked non-linearly. Examining the interconnections between ideas in an encyclopedia, for instance, requires jumping around in a text-based information system. Textual material is most easily searched for strings of symbols in close physical proximity (e.g., locating all paragraphs in a document which contain the phrases "software engineering" and "Prolog" and "expert systems"). Such key-word retrieval systems may locate less than twenty percent of the references relevant to a particular search [Blair & Maron, 1985].

To illustrate the rather abstract points made about knowledge representation so far, one emerging type of representational architecture, "hypermedia," will be defined and its functions examined. Hypermedia is a knowledge representation format composed of interconnected nodes of information. A node might contain text, data files, graphics, images, code, animation, or some mixture of these. Nodes can be arbitrarily large or small, but generally embody the equivalent of a few sentences to several pages of information. Further, they can have multiple embedded links to other nodes.

Links are associative paths between nodes. They can be as simple as a connection between an origin and a destination, or can have a variety of properties (such as purpose and direction). Links allow the creation of a conceptual web with complex interdependencies among nodes. This provides a framework for nonlinear representations of knowledge.

One way to conceptualize a simple hypermedia system is to compare this architecture of nodes and links to long-term human memory. Ideas are stored in the mind associationally; the word "apple" conjures up botanic, gustatory, computational, corporate, and theological dimensions. Imagine "apple" as a single node, with multiple links spreading out to other nodes that describe alternative meanings.

If an encyclopedia were organized on this basis, its knowledge would be more accessible than in the alphabetically sequential form used. Readers could browse by following links or conduct searches which would include the link structure itself (e.g. finding every paragraph that contains the words "apple" and "tree," but not "snake" and is linked to a paragraph containing the word "orchard"). If a visual representation of the link structure itself were available, one could navigate in the network of nodes by "flying" a route through the links or by "teleporting" from one node to another.

Advantages of Hypermedia

Nonlinear knowledge representation is superior to linear formats such as text for specific applications. Researching a topic referenced in a variety of interrelated linear documents can be frustrating, because of the difficulty of locating data in unrelated documents. A hypermedia system, in contrast, allows the user to follow a web of connections when tracing knowledge

scattered in multiple sources. (This is akin to the proverbial needle found in the haystack acting as a magnet to collect any remaining needles.)

With hypermedia, documentation can serve as a source for training; a user unfamiliar with the knowledge space can be guided along prestructured paths. Usually new workers need substantial amounts of help from a personal mentor to master a large-system design project like the space station. Productivity would increase, if a hypermedia documentation system could assume some of the responsibility for educating apprentices. In addition, use of a nonlinear representation that mimics human associational memory may give all users greater recall of material in the knowledge base, since the network's conceptual structure more closely mirrors their own mental models of information.

Using text as a method of organizing thoughts--about programming, authoring, design, or problem solving--can be difficult, since a linear format does not facilitate collecting and integrating a variety of approaches to the task. Current outline processors are limited to sequencing ideas hierarchically. The advantage of hypermedia is that concepts can be interrelated in a more complex manner, so that the brainstorming and synthesis aspects of knowledge creation are made easier. Hypermedia enables both the capture of divergent mental models (as nodes) and their convergence into a coherent strategy (by linking these nodes into a semantic network).

Team collaboration on a project is also enhanced by nonlinear media, because annotations and suggested revisions can be readily incorporated into a document. For example, a chunk of code and related documentation could be circulated electronically to multiple reviewers; the comments of each could be repeatedly attached, labeled,

and linked until the final hyperversion captured the collective wisdom of the group. In contrast, collecting from team members opinions and amendments on a document in standard text format is a very unwieldy procedure.

Finally, hypermedia formats support modularity of information, a vital strategy in large-system development projects. The same node of information can be referenced from multiple locations, minimizing duplication and overlap. This allows greater customization of documents (through tailoring the order and availability of segments); reduces the volume of archival material (since information used in many documents is stored in a single place); and facilitates revision (because only one node need be altered to create changes throughout the knowledge base).

Thus, hypermedia is a representation system well-suited for conceptual exploration, retrieval, training, retention, group collaboration, customization, and revision. The spectrum of functions a particular hypermedia system supports though will depend on what balance among these activities is most important to users.

Illustrative Hypertext Systems

Work in hypermedia is in the exploratory stage, the systems currently in use being prototypes in the early phases of usage. These systems are generally described as hypertext to indicate that they do not yet support the full range of representations implied by hypermedia. Robust second-generation projects which build on the lessons from these initial attempts will emerge over the next several years. Several hypertext applications which illustrate features of particular interest for postsecondary vocational, technical, and adult education are summarized below.

NoteCards, a hypertext system developed at Xerox Palo Alto Research Center (PARC), is an extensible environment for manipulating ideas. Idea processing consists of three types of activities: acquisition, analysis, and exposition [Halasz, Moran, & Trigg, 1987]. NoteCards is designed to:

- facilitate the manipulation of symbols that represent ideas and their interconnections;
- store and retrieve structured networks of ideas; and
- provide tools for tailoring the generic hypertext representation to the needs of specialized domains.

The metaphor underlying this hypertext system is a common set of 3x5 note cards, electronically represented as nodes. Links interconnect these nodes into structured networks, through which the user can navigate while searching. Customized nodes and links can be created. For example, Browser cards facilitate a user's traversing or editing subnetworks (the equivalent of composite nodes). FileBoxes are specialized cards, which provide a hierarchical organization for cards independent of their network interconnections.

Typical applications of NoteCards include authoring papers, providing a medium for competitive argumentation among different hypotheses, and supporting a computer-based training environment. As the range of these uses suggests, this hypertext is designed to be very flexible within the overall concept of idea bases (as opposed to data bases, management information systems, or knowledge bases).

Boxer is a programming language with nonlinear linking capabilities [diSessa, 1986]. The goal underlying Boxer's development is to produce an environment for programming which is powerful, but easy to learn and use (even for novices or children). Human factors and cognitive-science approaches are central to the design of this programming

system, with an emphasis on advanced features for presentation, structuring, and contextual application. For example, Boxer is well-suited to direct manipulation of standard programming objects, device programming, constructing customized interfaces, and building computational microworlds (limited alternative realities)--a concept discussed in detail in the User Interface portion of this chapter.

The fundamental unit of information in this programming environment is a box (similar to a node that is customized for code manipulation). Boxes can be hierarchically nested; for example, a Boxer program is a box which contains different types of internal boxes. These include boxes for input and output variables, besides other boxes that determine how variables are processed. The hypertext aspect of Boxer comes from its inclusion of ports, which allow boxes to be viewed and altered at multiple places in the overall programming environment. Ports have capabilities for link types, paths, procedural attachment, and node attributes. The same piece of code can simultaneously be part of many programs and accessible from each.

Boxer's integrated functionalities include text processing and structured filing, the ability to use and modify prewritten programs, database features, graphics capabilities, and tools for programming from scratch [diSessa, 1985]. This environment illustrates promising directions for improving software development. Too, it demonstrates how supporting nonlinear networks within the code itself can simplify the programming process.

Several projects have focused on using a hypermedia format to increase user mastery of the knowledge in a database. One such program, Intermedia, is being developed by the Institute for Research in Information and

Scholarship (IRIS) at Brown University. This hypermedia project is the latest in an evolutionary series of electronic information systems [Yankelovitch, Meyrowitz, & van Dam, 1985].

Intermedia enables browsing through multi-media information that is linked, cross-referenced, and annotated. System authors can access an integrated set of tools which include text processor, graphics editor, timeline editor, scanned-image viewer, plus an application to view and manipulate three-dimensional models. Future plans include the development of segment, map, video, and animation editors, as well as access to CD-ROM data [Garrett, Smith, & Meyrowitz, 1986].

A second group of hypertext knowledge transfer applications has been developed using HyperTIES (Hypertext based on The Interactive Encyclopedia System) at the Human-Computer Interaction Laboratory, University of Maryland. TIES was developed to facilitate user-browsing through instructional databases with an underlying hypertext architecture. The system is designed to maximize ease of use for both readers and authors and has an explicit instructional model [Shneiderman & Morariu, 1986]. HyperTIES is being expanded to include an advanced browser (with string search, bookmarks, multiple windows, and user annotation) and sophisticated authoring capabilities. Videodisc and touchscreen support are also under development [Shneiderman, 1987].

A prototype electronic encyclopedia with a hypermedia substrate was partially developed at Atari [Weyer & Borning, 1985]. The four metaphors used in the design of the knowledge base were model (a representation of some knowledge), tour (a particular path through some model), filter (an intelligent interface that tailors a model to a particular user), and guide (an intelligent electronic

agent that selects tours and provides help). Object-oriented hypermedia links along with embedded simulations provided a richer representational structure than the typical linear encyclopedia format.

An optical disc research prototype, Palenque, is being developed at the Bank Street College of Education [Wilson, 1987]. This knowledge transfer hypermedia system uses a CD-ROM (Compact Disc--Read Only Memory) with General Electric's Digital Video Interactive (DVI) technology. Palenque is designed so that children and their families can browse a database about a Mayan temple; the information is organized both topically (as a museum with four theme rooms) and spatially (so that the user can "walk" through the temple). When supplemented by a structured network of graphics, sound, text, narration, slides, motion video, and simulation, virtual travel is a powerful motivational strategy.

As the systems described above illustrate, hypermedia is a powerful means of knowledge transfer. The strengths of this representation are 1) immediate access to information scattered among various sources and 2) guided paths that sequence the user's exposure to data and make interrelationships explicit. Cognitive principles of learning, which support the concept of hypermedia-based educational environments, include active structural networks, schema theory, web learning, and generative processing [Jonassen, 1986].

This brief summary of illustrative research in nonlinear knowledge representations has only scratched the surface. Summaries of hypermedia for general audiences are given in Conklin [1987] and Pea [1987]. Commercial interest in hypermedia is growing rapidly; four nonlinear applications have appeared for Apple's Macintosh (one

bundled as system software) and two for IBM PC compatibles.

Operational Challenges

Limits typical of first-generation systems (e.g. computational delays, deficient visual representations of the web structure) will gradually disappear as second-generation hypermedia systems and more powerful workstations evolve. More critical problems that may constrain the ultimate usefulness of hypermedia are disorientation, cognitive overhead, combinatorial explosion, and collective communications dysfunctions, all of which are summarized below.

Information organized in a complex manner poses a potential problem of user disorientation. In a linear medium, one can readily evaluate the extent to which a document's information has been traversed (how many pages read, how many left) and where a particular piece of data is located (chapter, section, paragraph). Large hyperdocuments may be more confusing. In a web of thousands--or millions--of nodes, how does one target define a location in the network, establish a desired direction to move, or blaze a trail that will indicate nodes already scanned? In a non-hierarchical structure, what type of system should be used to indicate where a piece of data has been stored? Research is underway to develop sophisticated visual-spatial interfaces to address these problems [Fairchild, 1984], but for networks with large numbers of nodes and links this will be difficult.

Even if a user familiar with a particular network experiences no disorientation, working in a hypermedia knowledge base entails some extra cognitive overhead. When entering material, the author must consider how to link new information to the existing web. At each node, users must choose from multiple alternatives which link to

follow, while keeping track of their orientation in a complex multidimensional structure. The richness of a nonlinear representation carries a risk of potential intellectual indigestion, loss of goal-directedness, and cognitive entropy. Unless a hypermedia system is designed carefully from a human factors perspective, increasing the size of the knowledge base may carry a cost of decreasing its usability. Lenat [1986] is developing a theoretical framework for resolving these types of problems, based on his work in building a large knowledge base of real-world facts and heuristics with embedded reasoning methods.

The availability of multiple types of representations in a hypermedia system often compounds this problem. Although access to representational alternatives allows a user to tailor input to his individual cognitive style, while it enables an author to choose the format best suited for entering material, coping with multiple formats adds to cognitive overload. Little is known about which representational ecologies are functional for different task situations.

Combinatorial explosion (being overwhelmed by alternative possibilities) poses another type of potential limit. Consider the two extremes of interconnectedness among nodes: if all nodes are linked to each other, the network is meaningless; if each node is connected to only a preceding and a following node, the medium is linear. Hypermedia formats are useful only when balanced between these extremes.

The number of links generated by adding an additional node to a network will vary depending on the type of knowledge being stored, the objectives of the contextual material, and the sophistication of the user. Suppose that many vital, subtle interrelationships exist in the network's material. Although some new nodes will simply

annotate single existing nodes, a substantial proportion of nodes, when added, may require multiple links. Larger knowledge bases require more links to integrate additional material (because nodes that discuss related issues will already be present). In a worst-case situation, combinatorial explosion takes place. Each node adds so many new links that the difficulty of comprehending and maintaining the web exceeds the benefits of a nonlinear format.

One strategy for solving this problem is to aggregate subnetworks into composite nodes that chunk material on a higher level of abstraction. Such an approach is being explored in second-generation hypermedia systems--but creating another dimension of hierarchy complicates the representational architecture and, unless implemented in a manner transparent to users, may also increase disorientation and cognitive overload.

These potential limits are particularly acute in on-line, shared hypermedia systems. The user of a collegial electronic knowledge base may find that, since last entering the system, familiar paths have changed and new material has appeared. Links that seem intuitively obvious to one author may be puzzling to another. "Tower of Babel" communication dysfunctions are possible with a large knowledge base in which multiple users can alter the fundamental medium of interaction.

In summary, problems of disorientation, cognitive overhead, combinatorial explosion, and collective communications dysfunctions reflect the intricacy of working with a knowledge base rather than a database. Knowledge is intrinsically complex, and transforming information to knowledge involves gaining a goal-directed, contextual understanding of the application domain. However, knowledge is much more useful in task performance

than mere data or information, and the effort required to use a knowledge base may well be outweighed by gains in efficiency and effectiveness. Also, instructional design principles for intelligent tutoring systems may generalize to aid these broader problems of knowledge transfer [Dede & Swigger, 1988].

User Interfaces

A crucial aspect of any application is the interface, since the utility of any computer-based tool can be no greater than its accessibility. If mastering a job-performance aid is perceived as too complex, many workers will ignore its existence, or fail to tap its full potential. Unfortunately, more powerful applications require more complex interfaces to support the range of features.

Issues in User Interface Design

As researchers gain experience in constructing systems for knowledge creation, capture, transfer, and utilization, themes emerging as important design objectives include

- building resilient interfaces that facilitate management of trouble, though are not "idiot-proof;"
- developing user interface management systems (UIMS) that offer intelligent assistance to novice or occasional users, but also incorporate powerful command sets for more sophisticated practitioners; and
- providing support to the user in making decisions, though not by recommending solutions.

Cognitive engineering approaches--based on human factors, cognitive science, and ergonomics--are being developed to implement these heuristics [Norman, 1987].

The complexities of human interaction with an advanced computational environment preclude anticipating all possible problems and misunderstandings, so the goal of an "idiot-proof" interface is misdirected. Instead of attempting to avoid all possible problems for any user (a strategy likely to render the power of a knowledge base inaccessible), the focus of design is shifting towards managing trouble and providing resiliency. The concept of "repair" (support in recognizing and correcting difficulties) is becoming central to advanced interface construction [Brown, 1986].

Underlying this approach is the assumption that the user will have a common-sense understanding of how the system functions. The interface needs to be a "glass box" that makes operations sufficiently transparent to users, who can then apply them in the face of malfunctions, new situations, and errors. Such user control also allows tailoring the system interface to a person's level of expertise, individual cognitive style, or work role.

A system that competes for control of the decision-making process by offering solutions rather than advice only causes more problems, when, for example, two parties have overlapping authority and responsibility, which can easily lead to double-bind dynamics. Also, the less-than-optimal performance of current expert systems necessitates human editing of machine choices to filter out poor selections; this can negate many of the productivity gains of an automated knowledge-based system [Woods, 1986].

Complex systems have a variety of attributes which make them hard for users to understand and control. Unlike mechanical artifacts, information systems are opaque: function cannot be inferred from structure. As an illustration, by examining the parts of a lawnmower and their connections, users can form a qualitative causal

model of how it operates. With physical systems, people can develop mental models based on real-world experiences with wheels, springs, screws, etc [Gentner & Stevens, 1983]. A comparable analysis is not possible with a word processor. At present, beyond simplistic analogies to file cabinets, causal metaphors which provide semantic rationalizations for information systems do not exist.

This lack of transparency is aggravated by the ability of information systems to support multiple processes simultaneously, so that a person is confronted by several interacting "black boxes." A related difficulty in understanding information systems is their functional complexity. Users encounter many linked applications (word processors, programming tools, electronic message systems), each of which has hierarchical layers of features.

A final level of uncertainty results from the ambiguity inherent in any interactive system. Just as understanding a person's utterances often draws on a shared comprehension of the subject under discussion, collaborative action between a user and an intelligent tool requires a mutual sense of purpose. For instance, written instructions for assembling an artifact (such as a bicycle) might be confusing to a novice. Only when the parts have finally been assembled do the directions retrospectively make sense. In like fashion, misunderstanding about the "conversational postulates" underlying an interaction with an information system causes many an operational problem [Suchman, 1985].

These five attributes of information systems--opacity, lack of causal metaphors, multiple simultaneous processes, functional complexity, and inherent ambiguity--make interface design for ultimate understanding and control a difficult objective [Brown, 1986]. Still, however,

approaches which may resolve these problems are beginning to emerge, driven by a recognition that user acceptance and mastery of advanced job-performance aids is central to increasing productivity.

Illustrative Promising Directions

When executing tasks using an information tool, a user must grasp how the system operates. In doing so, he constructs a mental model that will help in coping with unexpected troubles. Research on how people use mental models to understand complex systems indicates that many fundamental questions remain to be answered [Rouse & Morris, 1986].

Semantic Rationalization Strategies

A good conceptual model of an interface should be clear, cover the full range of operation, and use a metaphor rich enough to capture the spectrum of available features. For example, thinking of a word processor as "like a typewriter" is limiting because features such as cutting and pasting text, searching for strings of characters, or justifying paragraphs are omitted by this metaphor [Miller, 1986].

"Self-explicating" systems are an important emerging design strategy. One type of self-explicating interface uses graphics to create objects that are manipulable by the user in the same manner as their real-world counterparts. For example, a doorknob icon induces an impulse to turn and an expectation that something will open. Such a mimetic interface is an imitation of the semantics of the underlying real-world referents [Laurel, 1986]. To facilitate the mastery of operational commands, the system designer can build on common-sense knowledge without having to impart new skills.

First-person (or direct manipulation) interfaces allow users to work directly with the domain (e.g. turning a

doorknob icon). In contrast, second-person interfaces (discussed later) require the user to give syntax-laden commands to a second party, the computer, which then carries out the actions. Direct manipulation interfaces provide [Shneiderman, 1983]:

1) continuous representation of the object of interest,
2) labeled buttons or keys to depress (instead of complex syntactical commands), and
3) rapid incremental reversible operations, whose impact on the object of interest is immediately visible.

Examples include graphical programming environments such as ThingLab [Borning, 1981], computer-aided design (CAD) interfaces, the Macintosh operating system, and spreadsheets.

On the other hand, direct-manipulation interfaces are limited in their ability to execute repetitive operations, handle variables, distinguish individual elements from a class of similar elements, and control actions with precision [Hutchins, Hollan, & Norman, 1987]. Nonetheless, they enhance user understanding and control by supporting common-sense, mimetic operations. For example, the Whiteboards system is the electronic equivalent of an office corkboard; users rapidly master elements of Xerox's Cedar programming environment by interacting with icons in a database, as one would manipulate equivalent collections of objects on real-world corkboards and whiteboards [Donahue & Widom, 1986].

Ultimately, the work on mimetic interfaces may produce full-fledged "artificial realities." These interfaces would utilize 3-D imagery, elaborate user input devices (such as gesture gloves for grasping computational objects), and hypermedia representations to create an

alternative universe controlled by the user and optimized to performing a particular set of tasks [Fairchild & Gullichsen, 1986]. Gibson [1984] describes a fictional, but plausible society in which databases are accessed through a collective artificial reality.

The three components of an artificial reality are imagery, which immerses the user in a visual space; modeling, which allows the images presented to behave in consistent, meaningful ways; and an interface, which allows interaction with the images in a manner similar to real-world experiences [Foley, 1987]. For example, the head-mounted display developed by Fisher, McGreevy, and Humphries at NASA's Ames Research Center projects to its wearer the images that a robot is "seeing." Such a display could be augmented with a device (such as VPL Research's DataGlove™) that would allow the user to "grasp" these images and manipulate them, receiving pressure feedback from the glove comparable to the sensory stimulation that would be received from the object being modeled. A DataSuit to cover the human frame might be the next step.

"Microworlds" (interactive simulated environments with mutable rules of operation) provide limited alternative realities tailored to education. For example, the Alternate Reality Kit (ARK) allows users to manipulate the laws of physics and experience how everyday activities (such as throwing a ball) change as a result [Smith, 1987]. Object-oriented interfaces of this type present powerful ways to increase motivation and understanding.

Educating users on how an information system functions is important because otherwise interactions appear "magical." People can begin to use a non-mimetic, second-person interface by memorizing nonsensical (to them) commands which accomplish specific system actions. However, as tasks become more complex, the number of

incantations to be remembered grows rapidly and may become overwhelming. Further, when trouble arises, users have no idea how to remedy the situation unless they previously have memorized an equally magical way of responding to this particular predicament.

Coordinating Multiple, Complex, Simultaneous Processes

A second limit on user control of an information tool is functional complexity. Many applications may be active at the same time, each having hierarchical layers of features. This functional complexity requires a mastery of procedural skills that many users find difficult to attain [Sheil, 1982]. Several approaches to interface design are addressing this problem.

One strategy is to support user "linearizing": performing several tasks while switching among them [Cypher, 1987]. People are adept at linearizing in everyday settings; for example, most can walk, chew gum, and converse with someone else simultaneously. However, multiple parallel activities entail cognitive overhead: competing priorities must be scheduled; the context of an interrupted activity must be stored for later recall; and actions must be sequenced for mutual compatibility. For example, crossing a busy street may suspend conversation temporarily, while enunciating a word may require shifting the wad of gum.

"Windows" are one approach to linearizing computational activities; they create multiple virtual screens, each with its own activity context. Card and Henderson's Rooms [1987] is a window-manager system with a mimetic interface. Each room (window) has furniture (computational tools appropriate to a particular task) and doors (traversals to related applications). Such a strategy is a promising alternative to interfaces that

impose a single integrated structure on a package of applications (e.g. Lotus' 1-2-3™).

The Goals, Operators, Methods, and Selection Rules Model (GOMS) [Card, Moran, & Newell, 1983] provides a theory for how users cope with functional complexity. Domain goals are accomplished by selecting the most effective strategy from alternative sequences of system actions. Two psychological barriers to attaining this type of expertise are production bias and assimilation bias [Carroll & Rosson, 1987]. To accomplish a task quickly, a user will maintain high immediate production by continuing to use a few basic problem-solving procedures, rather than master new, more powerful command sequences; or attempt to assimilate new phenomena by treating them as minor variations of already understood situations. For example, electronic desktop metaphors sometimes confuse users, who find that computational "folders" differ in crucial aspects from their real-world counterparts.

Where direct manipulation strategies are not effective, a different type of self-explicating interface can aid in overcoming production and assimilation problems. Second-person interfaces (in which a computational actor is told by the user to accomplish a task) can use intelligent explanatory abilities to handle situations where error, malfunction, or novelty causes confusion. (These advice-giving interfaces are a subclass of the larger field of intelligent tutoring systems [Dede, 1986].)

A good review of interfaces effective in facilitating user learning appears in Burton [1986]. Historically, these explanatory environments have proven difficult to construct, expensive to maintain, and limited by their specificity to a single domain. Researchers are now exploring intelligent authoring systems to solve this

problem. Two examples are the Xerox Instructional Design Environment (IDE), which incorporates a hypertext representation structure [Russell, Moran, & Jordan; 1987], and the Teacher's Apprentice [Lewis, Milson, & Anderson; 1987].

Advances in advice-giving interfaces depend on resolving several types of research issues. A general theory of coaching needs to be developed. Everyone knows that poor or obtrusive advice is often worse than none at all. Behavioral evaluation of the effectiveness of explicating interfaces is also inadequate. In addition, adding an explanatory function to an expert system optimized for decision making can be challenging [Clancey, 1987]. Still, enough progress has been made in this regard that this type of self-explication may be one of the next major applications for expert systems [Carroll & McKendree, 1987].

However, improving user learning by enhancing the system interface need not hinge on advances in artificial intelligence. Presenting to users the sequence of actions to be taken in performing a task may also suggest to them patterns of error or suboptimal performance. Such "cognitive audit trails" provide a means of documenting skill acquisition, and support learning while doing. "Consciousness sensors" monitor the user's motivation and mood by tracking respiration, skin conductivity, heart rate, and other physiological measures, and aim to improve productivity through performance feedback [Dede, 1987].

Resolving Ambiguity

Linearizing aids and second-person explanatory environments are two interface design approaches which can reduce confusion resulting from the functional complexity and multiple processes of knowledge bases. A final problem is that of ambiguity: intrinsically, interactive systems

depend on conversational postulates about the task being performed. The task mapping involved in moving from the goal (e.g. create a striking overhead transparency) to the action the interface makes available can be overwhelming. "Sorcerer's apprentice" outcomes can easily arise from instructions misinterpreted by an information system.

One solution to task-mapping problems might be natural-language interfaces: a person's goal descriptions in a familiar communication medium are translated by the machine to command sequences. The interaction is built around existing skills. For instance, conversational skills could be applied to user-computer interactions, where the expressiveness of natural language would provide the foundation for a rich menu of possible commands.

However, substantial barriers to implementing true natural-language interfaces exist. Natural-language understanding has proven a very difficult problem in artificial intelligence, and major research issues are still unresolved [Perrault & Grosz, 1986]. Building contextual knowledge into an interface involves multiple, simultaneous levels of discourse [Reichman, 1987]. While implementing a natural-language interface can represent a major proportion of total system cost, the final product, compared to human conversation, may be limited in capability [Miller, 1986].

Alternatively, the interface can be made an intelligent, semi-autonomous agent. One example of this approach is The Information Lens, an intelligent information-sharing system [Malone et al, 1987]. Studies of knowledge transfer in organizations indicate that people use cognitive, social, and economic strategies in filtering incoming data. An intelligent information sharing system can use semi-structured (frame-based) message types which are automatically processed through

intelligent editing mechanisms prespecified by users to accomplish this filtering.

The use of an intelligent agent provides a substantial degree of user control in the user-computer interaction, as well as supporting group problem solving through an improved organizational interface for data management. Also, such a capability would be very useful in an "information utility" (a service providing integrated access both to information sources--newspapers, radio and television stations, magazines and journals, books, databases, electronic mail and computer conferencing services--and to tools for manipulating, filtering, synthesizing, and sharing that information) [Dede, 1985b]. In general, semi-structured interfaces seem a promising approach to task mapping.

Embedded intelligent agents could also improve personal information-retrieval capabilities. As Brown and Moskovitz [1985] discuss, secretaries are adept at finding documents in files even when the request includes erroneous information (i.e. wrong title or year). People use sophisticated, but largely intuitive search heuristics; if these could be incorporated into an expert system in a knowledge base, even ambiguous or incomplete instructions could be executed. In addition, a profile of the user's style in assimilating information could be included, so that requested data would be presented in a format (e.g. tables, pie charts) suitable to that person.

Though natural-language capabilities and semi-autonomous agents require substantial resources compared to "dumb" interfaces, the payoffs for building intelligence into an information system transcend the problem of resolving ambiguity. How motivated a user is to interact with an information system may depend in part on its ability to support perceptions of contact with an

intelligent agent. Seven types of motivations appear to sustain human interest in computer-based learning environments: challenge, fantasy, curiosity, and control are "individual" motivating factors; cooperation, competition, and recognition are "interpersonal" ones [Malone & Lepper, 1985].

To the extent that an information-system interface can provide cooperation, competition, and recognition (intelligence embedded in the system itself or computer-supported, cooperative work features), user motivation to learn from its knowledge base will be enhanced. In general, designing interfaces to maximize motivation (e.g. mimesis as a means to enhance fantasy) may be as crucial as tailoring the user-computer interaction to minimize cognitive load.

In summary, sophisticated means to improve user performance are being explored in leading-edge research on information-system interfaces. As these capabilities become robust enough to be used in workplace and educational environments, and as the computational power they require becomes affordable, the skills needed by users to optimize their interactions with tools for learning and job performance will alter. This poses both challenges and opportunities for postsecondary vocational, technical, and adult education.

Computer-Supported Cooperative Work

Computer-Supported Cooperative Work (CSCW) is an emerging field that focuses on improving group productivity and effectiveness in shared computational environments. Research topics currently being investigated include collaborative design technology (surfacing collective assumptions, resolving conflicts, and developing shared models of a task) and organizational interfaces (text sharing, project management, and

collaborative authoring systems). These build on the concept of multiuser interfaces (the integration of inputs from several users manipulating a common workspace).

Collaborative Design Technology

The Software Technology Program at the Microelectronics and Computer Technology Consortium has been exploring how Issue Based Information Systems (IBIS) can help software designers by supporting structured, collective conversations about planning [Conklin, 1986]. A number of design activities might be improved by using such systems. First, collaborative information systems can help with coordinating "wicked" problems (no definitive formulation, no stopping rule, "satisficing" solutions) [Rittel & Webber, 1973]. Many high-tech engineering and manufacturing applications are classic examples of wicked problems; design tools that can manage such cognitive and organizational complexity are very useful.

Second, such collaborative design technologies can capture the reasoning processes leading to a design decision. Documenting evolution of a design, important in itself, can also help to minimize "backtracking" problems, should a particular avenue of attack prove to be fruitless. All too often, the institutional memory of a rationale has eroded, forcing the project team to reiterate the design process. A prototypical documentation system for rationale capture is Xerox's Instructional Design Environment (IDE), which uses a hypertext representation system to build an explicit chain of reasoning between general learning theory principles and specific choices made by the designer in scripting a lesson [Russell, Moran, & Jordan; 1987].

Finally, computational support that models the design process itself can improve productivity and effectiveness.

MCC has developed ISAAC, a hypertext format for structuring design decisions based on the following model:

1) delineate an issue;
2) develop a set of alternative resolutions;
3) analyze these competing alternatives on criteria such as cost, performance, reliability, and security; and
4) make a commitment to one alternative, with a subjective confidence rating on the correctness and stability of the commitment.

Sharing such models, by linking individual hypertext representations, can empower a design conversation in which competing approaches are explicitly presented and critiqued, with a collective mental model eventually being internalized by the entire project team. ISAAC is one of a set of integrated tools being developed as part of Leonardo™, an overall MCC software design environment [Conklin & Richter, 1985].

Structured, machine-mediated communication underlies many types of CSCW. For example, as a step beyond electronic mail systems, computer-based teleconferencing facilities are being developed. These allow the real-time exchange of multimedia information, besides access to a computational environment integrated across geographically dispersed information systems. Lantz [1986] presents a prototypical hardware architecture for structuring these networks using distributed computational support.

Once established, such a shared workspace can aid in developing, new types of task performance processes. As an illustration, Lowe [1985] describes methods for cooperatively indexing, evaluating, and synthesizing information through multiple-user interactions with a common database. In the Synview system, a structured representation is used to formalize group reasoning and

debate processes concerning the accuracy and utility of alternative information sources. The very structure of an argument is stored as another dimension of knowledge encoded in the Synview system. This allows users to examine informed opinions about the quality of information they are obtaining. Such a CSCW approach can improve the accuracy, accessibility, and integration of knowledge bases.

Overall, while the technical and representational issues involved in implementing machine-mediated communication are significant, these collaborative environments offer several potential benefits:

- geographically distant people can exchange information readily,
- the documentation process (often the most neglected part of meetings) can be partially automated, and
- group interaction can be structured to be more productive.

Electronic mail and computer conferencing are preliminary steps toward achieving a "global village" within an organization; now, CSCW systems capable of realizing the other two benefits are emerging.

As an illustration, Xerox's Colab is an experimental meeting room set up to study how shared computational networks can be used to enhance problem solving in face-to-face group interactions [Stefik et al, 1987]. Colab generalizes the text-editing concept of What You See Is What You Get (WYSIWYG) to WYSIWIS (What You See Is What I See); consistent images of shared information are presented to all participants in the meeting. WYSIWIS is used to support the analysis of tasks into parallel activities that various members of a group can accomplish simultaneously in a common workspace.

For example, Cognoter is a Colab tool designed for collective preparation of presentations; its use results in an annotated outline of ideas and associated text. Meetings are structured into three phases--brainstorming, organizing, and evaluation--with Cognoter providing a shared workspace for recording and commenting on ideas. A direct manipulation interface is provided for entering, spatially rearranging, linking, and deleting information. An underlying hypertext representation allows the creation of semantic nets through transitivity and grouping operations. The outcome of a Cognoter session is a collective, fully documented mental model of a presentation.

Argnoter is a Colab tool used for presenting and evaluating design proposals; its focus is to facilitate discovering, understanding, and evaluating disagreements in a meeting. Personal attachment to certain positions, unstated assumptions, and unstated criteria often are hidden factors which cloud processes of cooperation, compromise, and group decision making. Argnoter segments meetings into three phases: proposing, arguing, and evaluating; the outcome is either a collective, documented resolution of the competing proposals or an explicit agreement to disagree.

Improving tools such as these will require research on both technical issues (such as the best control mechanism to use for mediating the interaction of multiple users in the same workspace) and cognitive issues (such as how the writing process can be structured to optimize group interaction during different phases of the meeting). This work in CSCW is crucial to improving the productivity of personnel, such as managers, who spend most of their time in meetings, since standard office automation strategies have little impact on their task performance.

Organizational Interfaces

Malone [1986] distinguishes between a user interface (which connects an individual to the capabilities provided by a computer) and an organizational interface (which connects several users to each other and to capabilities provided by the computer). Applications using organizational interfaces include text-sharing systems (electronic mail, computer conferencing), project-management systems (which help in assigning people to tasks, constructing schedules, and allocating scarce resources), and collaborative writing systems (such as hypermedia authoring tools).

The design of organizational interfaces must take into account the problem-solving behavior unique to groups [Corkill & Lesser, 1983]. For example, though not an issue in user interfaces designed for individuals, filtering interagent communication requires careful computational control in CSCW systems to avoid an explosion of messages being passed among workstations. One approach to resolving this problem in an electronic mail system is the use of templates to structure different types of messages, thereby allowing the construction of intelligent filtering systems [Malone et al, 1986].

Also, goal conflicts among members can adversely affect group problem solving; organizational interfaces can be designed to improve this situation by providing mechanisms for coalition formation and confidentiality. Assigning subtasks to individual agents is another group function which CSCW systems must address; here, forming computer-based internal "markets" to bid on task assignments can be useful in enhancing institutional flexibility [Malone & Smith, 1986]. As discussed in the User Interface portion, enhancing interpersonal motivations (such as cooperation, competition, and

recognition) is also an important aspect of organizational interface design.

Filtering inter-agent communication, resolving goal conflicts, assigning subtasks, and intensifying interpersonal motivations, interface functions that researchers are just beginning to address, are intrinsic to group problem solving. From this work, new strategies for improving collaboration in scientific research may result. For example, based on semi-structured interviews, Kraut, Galegher, and Egido [1986] describe a model of collaborative-research relationships that involves stages of initiation, execution, and public presentation; evolution from one stage to another involves changes at both the interpersonal-relationship level and the task level.

Analysis of interview data reveals that establishing and maintaining personal relationships is central to collaborative efforts in scientific research. Given the geographic and institutional barriers typical of very large-scale development projects, CSCW design is challenged to create organizational interfaces that facilitate and support interpersonal contact as well as the exchange of information. This is a very difficult task but, unless progress is made, potentially productive groups separated by accidents of distance or organizational structure may not coalesce into collaborative activities even though placed in electronic contact.

Overall, CSCW research builds on prior work in computer-based communications, computer-based information services, and computer-based decision support. One product of CSCW efforts is likely to be Group Decision Support Systems (GDSSs), which can be classified into six general categories [Kraemer & King, 1986]:

1) electronic boardrooms (display technology),
2) teleconferencing facilities (communications technology),
3) local-area group nets (interactive conferencing capabilities),
4) information centers (knowledge bases and related tools),
5) decision conferences (structured decision models and protocols), and
6) collaboration laboratories (tools for joint authorship).

Research on these systems is evolving in two directions: studies in the nature of decision making, and development of technologically supported information systems to make group interactions more productive.

In time, GDSSs may provide several different types of benefits. On the affective level, they appear to encourage the involvement of individuals in group efforts and to build group cohesion. Organizationally, they can facilitate group decision making, reducing the time spent in speeding the process of meetings. On the cognitive level, GDSSs can increase the quality of information a team might use to reach a decision or generate a product.

In summary, work in CSCW is beginning to blur the distinction between the two types of applications systems characteristic of information-processing tasks [Danzinger & Kraemer, 1986]. Model-based systems flow from a decision-support, operations-research, management-science framework; the design perspective underlying these information systems is that problem solving via model building is the core of task performance. In contrast, operations-based systems build upon concepts from computer science, data processing, and management-information systems; here, problem finding is seen as the key activity

which information systems facilitate. Because of research in fields such as CSCW, data-based synthesis applications are now emerging. These information systems are designed to facilitate browsing through data in search of facts, linkages, and patterns; both problem-finding and problem-solving functionalities are supported.

However, substantial barriers remain to the evolution of CSCW systems. Technical problems include requirements for accessibility and flexibility in computing resources, display and graphics technology limitations, and the shortcomings of current software for modeling and analysis. An incomplete understanding of the decision-making process is a cognitive barrier to the utility of GDSSs. Finally, human resistance to changes in familiar operating procedures is a formidable obstacle.

Computer Hardware

The functionalities described so far (sophisticated knowledge representation and management, advanced user interfaces, computer-supported cooperative work) all require massive amounts of hardware power to implement. At present, small-scale, prototypical versions of such applications require the processing and memory capacities of leading-edge research workstations. Their widespread dissemination in the next decade, given the performance limitations of current microcomputer systems, seems unlikely. Even so, the required boost in hardware characteristics is no greater than that which has occurred from the first 8-bit machines of the late 1970's to the state-of-the-art microcomputers of today. Nor will cost be a barrier; the <u>least</u> expensive part of a future computer may be the electronics that power its functions. The keyboard, display, and drives (even the plastic case!) cost more to manufacture than the chips in the device.

The trend of exponential increases in power seems likely to continue for at least another decade, before fundamental physical limits (the speed of light, quantum-mechanical effects, entropy) slow the rate in advance of electronics [Drexler, 1986]. Whether evolution continues beyond that point will likely hinge on progress in optics, biotechnology, and parallel computer architectures. Mid-range trends for computer hardware include higher capacities; increased abilities to represent complexity and encompass a wide range of applications; and faster, smaller, and cheaper systems.

Architectures

Today's computing systems are still based primarily on linear, sequential architectures which process a single stream of data using a single stream of instructions. Advances have given a desktop PC the equivalent power of a large, 1960's era mainframe system at a fraction of the cost. Illustrative of recent changes is a comparison of four generations of Digital Equipment Corporation's MicroVAX™ computers.

EXHIBIT 2.3

MICROVAX SYSTEM COMPARISON

	Date	MIPS	Memory	Price ($)
MicroVAX I	10/83	0.36	2-5 MB	12,800
MicroVAX II	5/85	0.90	2-9 MB	14,000
MicroVAX 2000	2/87	0.90	4-6 MB	7,500
MicroVAX 3000	9/87	3.00	16-32 MB	75,000*

* Includes a license for 20 Users

Increasing functional capability together with decreasing physical size and cost are the result of technological evolution. Such benefits are achieved by changes in the microelectronics which comprise the system; however, computational speed is approaching the limits achievable with current silicon design.

One billion components per chip is the estimated state-of-the-art for the year 2000 [Meindl, 1987] and, as this level of integration is reached, the rate of increase in component density will slow. For example, components per chip increased by three orders of magnitude in the decade of the 1960's, and by two orders of magnitude in the 1970's; but less than a hundred-fold increase will occur in the 1980's, while the 1990's may see a gain of only ten-fold. Future significant increases in computer performance will require advances in parallel-processing architectures, large-scale integrated-circuit design, new chip substrates, and exotic technologies such as three-dimensional quantum-well superlattices.

Integrated circuits and microprocessors are the heart of any computing system. At this level, the two major determinants affecting functional capabilities are signal-processing speed and switching speed. Signal-processing speed, (the rate at which bits of data can be processed by the chip), varies with the number of components on a chip,

chip size, and the substrate material used in construction. Switching speed (the rate at which data can be sent through a circuit from one component to another on the chip or board) varies with board design, chip size and packing density.

Signal-processing speed has been increasing as a result of greater circuit density and improvements in chip substrate and construction technology. Presently a one square centimeter chip contains one million (1 Megabit) components. Near-term extrapolations indicate 4 Megabit chips will be commercially available by 1990, and somewhere between 10 and 100 million components per chip will be state-of-the-art by the year 2000.

Density approaching the 100 million component-per-chip range would require line widths of 0.1 microns (in contrast, the Intel 80386 is a 1.5 micron chip) and chip sizes of about 1,000 square millimeters. In order to accomplish such breakthroughs, microlithography (the underlying manufacturing process of "implanting" chips) would have to employ the use of electron-beam and ion systems.

Evolution in the basic materials used to construct chips will further contribute to the trends of increasing speed and decreasing cost. New materials, coupled with advanced techniques in crystal construction, will result in improvement in the crystal's carrier mobility (electron speed through circuit layers). Electrons in a heterostructure have been clocked at up to 20 million centimeters per second (cm/s), versus 6-8 million cm/s for an ordinary silicon device. To give a sense of what this means for processor speed, the limit for silicon transistors is around 20 GHz; and conventional GaAs, about 50 GHz. General Electric has demonstrated a

heterostructure transistor that operates at frequencies of up to 80 GHz [Brody, 1986].

Improvements in chip fabrication methods, wafer size, circuit density, and substrate compounds should all contribute to dramatic improvements in chip size and speed through the end of this century. Benefiting fully from gains in the signal-processing capabilities of chips will require similar improvements in methods of interconnection (or switching technology) between processors, to ensure faster computer architectures. Recent advances in superconductivity and optical-signal switching hold great promise for increasing these inter-chip capabilities.

Significant breakthroughs in superconductive material development have been achieved within the last eighteen months. Once perfected, these new materials, which can transmit electrical energy with no resistance, could be used in areas as "interconnects" (the circuitry, now typically composed of aluminum or copper, that links computer chips together). The potential results are a decrease in power dissipation and an increase in signal-transfer rate.

On the horizon are functional prototypes for an optical computer (optoelectronic), which utilizes laser light to pulse data between chips at rates of up to one gigabyte per second. The optoelectronic device uses coherent laser light to replace physical circuits, and gallium arsenide chips to produce the superfast integrated circuits required for parallel-processing applications [Hutcheson, 1986].

Switching speed has been improving (from 1 millionth of a second in mid-1960's, 1 billionth of a second by 1977, to an expected 10 trillionths of a second by 1990) and is expected to approach 1 trillionth of a second by the end of this century [Office of Technology Assessment,

1985]. However, the trend of increasing device speeds for both silicon and gallium arsenide components will slow towards the latter part of the 1990's, as the limits of these media are approached.

In summary, microprocessor technology remains a fundamental building block of advanced computing systems. New computational architectures such as parallel processing, which execute many software routines simultaneously instead of sequentially, will be required to run the complex software needed for advanced-user interfaces, expert systems, three-dimensional displays, plus manipulation of massive volumes of digitized information and new forms of knowledge representation. Work on such connectionist architectures is proceeding based on electronic simulation of neurobiological models [Hopfield & Tank, 1986], massively parallel processors arranged in a Boolean n-cube [Hillis, 1987], optical-neural computers [Dongarra, 1987], and many other variations. The equivalent of parallel processing in software design is also emerging [Hillis & Steele, 1986] and will be needed for the types of functional performance these hardware advances empower.

Secondary Storage

Computing systems make use of two kinds of memory storage. Random Access Storage (RAM) is chip-based, primary computer memory used to execute software and process data. In contrast, permanent, secondary storage encapsulates large volumes of data either in a magnetic medium, such as disk or tape, or in an optical medium (e.g. a compact disc).

Secondary computer storage systems have historically utilized magnetic disks or tapes. Storage capabilities range from approximately 0.5 megabytes (or roughly 100 pages) for a conventional 5 1/4 inch floppy disc to 1000

megabytes for the large hard-disk packs used with mainframe computers. Magnetic storage relies upon a thin film media and a "head" reader which travels over the surface of the disk (which, in the case of rigid hard-disk systems, rotates at speeds of 3600 rpm). The limits of conventional magnetic media are expected to be reached within the next decade due to physical constraints in density packing on thin film with the attainment of minimum head-reader heights over the thin film media [Bezold & Olson, 1986].

Optical storage technologies constitute the latest wave of mass-storage breakthroughs. Compact Disc-Read Only Memory (CD-ROM), Compact Disc-Write Once Read Many (CD-WORM) and Compact Disk-Interactive (CD-I) have boosted storage capacities by an order of magnitude or more. CD technology uses lasers to store data in a digital format on an optical-disk medium ranging in size from 4.7 to 12 inches in diameter. Storage densities for CD-ROM, which is used to archive (or store permanently) information, range from 500 megabytes to 1 gigabyte per disc. The Write-Once-Read-Many (WORM) format allows the user to store textual, numeric or image information a single time. A CD-I system expands upon this by storing text, numerics, images, graphics, or audio/visual formats all on the same disc; however, with the CD-I format, the "write" technology, which requires specialized equipment, generally is not available to the average user.

Access time for retrieval of information from optical storage has improved from a range of 400-500 milliseconds to a range of 200-300 milliseconds; this is still not as fast as magnetic storage systems, which can retrieve information in the 18 millisecond range. Optimization of compact disc access speed is still evolving, and software

driven optimizers (such as new indexing techniques) are expected to contribute to improvements.

A number of commercial optical-storage products have been recently introduced. For massive archival information, CD-WORM disks have been packaged in a "jukebox" system. The jukebox holds a number of optical disks, which store multi-media information formats for on-line access. One such system is the Optical Disk Storage and Retrieval Unit™ (ODSR) made by Perceptics International (formerly Optical Storage International).

This system contains 20 double-sided, removable WORM disks, each of which stores up to 2 gigabytes of information. The system cost is about $65,000. The ODSR can be linked to either an individual computer or a network via the Small Computer Systems Interface (SCSI) or the Intelligent Systems Interface (ISI). (The SCSI and ISI are industry standard interfaces which link optical-storage devices to computing systems.) Up to seven ODSRs can be linked together, creating a potential of 320 gigabytes of storage.

One problem raised by implementing an optical mass-storage and retrieval system is the task of capturing existing information in an electronic form suitable for storage. Some optical systems store information as an image, rather than in a revisable format. This may be appropriate for archival information, which is merely retrieved without change for historical purposes; but dynamic information, which is part of a production process, must be stored in a revisable, updatable form. Though it can optically store information in a revisable format, the WORM medium limits updating existing information. This limitation should be resolved by the next generation of optical storage (termed "erasable" optical storage), expected to emerge by the early 1990's.

A second challenge created by the implementation of optical storage is the conversion and capture of information which exists in a non-magnetic format, such as paper or micro-fiche. A promising strategy for resolving this problem is through the use of optical scanners, such as the Palantir Compound Document Processor™. These devices digitize text and images by scanning paper documents and converting the information into a revisable electronic format, which can then be treated as a conventional electronic file for storage and retrieval.

Significant improvements that optical storage offers over conventional paper/microfiche mass-storage systems include:

EXHIBIT 2.4

OPTICAL VS. CONVENTIONAL MASS STORAGE SYSTEMS

	Optical	Paper/Microfiche
Storage Density	200,000 pages/disc	3000 pages/drawer 260 pages/fiche
Storage Speed	Computer speed	By hand
Storage Cost	$0.008/pg.	Micromedia $0.01/pg.
Storage Space	200,000 pages on one 12" disc	200,000 pages in 180 file drawers
Retrieval Time	3 to 5 seconds (random access)	Minutes (sequential access)
Indexing	Automatic Multi-level	Manual limited levels
Shelf Life	15 year minimum possibly indefinite	100 yrs with proper processes, medium, and storage environment

Economies of scale in the production process will continue to drive down the cost of optical-disc and disc-reader technology.

Future innovations in storage technologies will likely stem from two advances:

- The development of an inexpensive "erasable" optical storage technology (or medium)
- The use of new types of energy devices to "burn" data into the recording medium

Early versions of erasable optical memories have recently appeared on the market. These initial entrants generally make use of magneto-optical or phase-changing media in order to provide the capability to read and write over the same medium numerous times [Tsunoda, 1985].

These erasable systems represent the first generation of optical-disk technology that will be able to compete with the multiple read/write capabilities of magnetic systems. At present, such products are not commercially competitive because of cost while production facilities for erasable systems are limited and do not enjoy the same economies of scale as more mature media. However, commercial varieties of erasable optical-storage systems are expected to emerge by the early 1990's. Second-generation erasable optical-storage technology will make greater use of phase-changing materials, which provide higher speed and disk densities than first-generation magneto-optical erasable technology.

Other expected advances in optical storage include the use of High Power Diode Lasers, which use a shorter wavelength to increase bit density on the storage medium. The shorter wavelength essentially allows smaller (and denser) bit-hole patterns. Frequency Domain Optical Storage, another laser-based system, permits the lasing light to be adjusted over a range of frequencies, thus allowing information bits to be overlapped, though at different frequencies. The data is then retrieved by adjusting the laser to the specific frequency used during

the writing process. This innovation could potentially increase the capacity of optical disks by a factor of 10 to 1,000 [Office of Technology Assessment, 1985].

Electron Beam recording for optical media is now under development. Electron beams operate at substantially higher frequencies and shorter wavelengths, providing even greater bit densities than with lasing light technology. Error rates are still unacceptably high; however, given the capability to control errors through error-detection algorithms, E-beam could boost storage up to 50 gigabytes per disc [Bezold & Olson, 1986].

In summary, mass-storage devices betoken a shift toward the use of optical technology, though magnetic media, because of rapid access times, will continue to play a role. RAM costs are expected to continue their exponential decline, so that microcomputer systems may have a standard RAM capacity of 20-30 megabytes by the late 1990's. Processor speeds for such systems will be in the range of 20-50 MIPS.

Telecommunications Hardware

Telecommunication of information is accomplished through either land-based or space-based systems. These are generally configured as:

- Digital microwaves via land-based transmitter/repeaters
- Land-based cables (coax-copper and fiber optical)
- FM radio transmissions
- High-frequency Ku and C band satellite transponders

Telecommunications capacity, or the capability to send greater volumes of information at a faster rate over distance, has been increasing at unprecedented rates. The following exhibit illustrates those increases due to improved telecommunications technology.

EXHIBIT 2.5

INCREASING TELECOMMUNICATIONS CAPACITY

300 bps (bits per second) data	Considered high-speed transmission at start of 1980's
1.2-2.4 kbps (kilobits/sec) common now	Data transmission speed
1.54 mbps (megabits/sec) carriers	Telephone network T1
6 mbps	Today's satellite transponders
16 mbps	Extremely clean 4-wire copper circuit under ideal conditions (not usually available)
42-160 mbps	Today's fiber-optic technology
2 gbps (billion bits/sec) by Bell	Rate recently achieved Labs for an 80 mile fiber-optic transmission using no amplification

Two major technological trends for telecommunications are expected to continue through the next decade:

1) increasing transmission capacity; and
2) standardization of heterogeneous hardware and software, resulting in improved integration among different vendors.

Augmenting Capabilities

Increasing transmission capacity will result primarily from technological improvements in fiber-optic cabling and satellite transponders. Fiber-optic cabling is composed of ultrahigh-purity glass-fiber lightguides. Flexible, strong, and lightweight, these fibers carry audio, video, or data transmission in the form of coherent light pulses generated by diode lasers. Fiber optics are not adversely affected by electromagnetic fields, can carry orders of

magnitude more information than a copper co-axial cable, and require fewer signal repeaters between spans than copper cabling. For example, a quarter-inch diameter optical cable with two fibers carries as much data as a 3-inch copper cable with 20,000 wires.

Fiber-optic cabling is presently being employed for transoceanic, long-haul domestic trunks, and metropolitan systems. Illustrative of this is a recent Bell system long-haul system: a 900-mile, single-mode lightguide which operates at 432 mbps. This system carries up to 6,048 voice circuits over a single fiber in each direction [Kay & Powell, 1984]. These networks are replacing amortized co-axial systems, and by the 1990's are expected to begin penetrating the residential market. By the end of this century, fiber optics will be the dominant transmission medium for all fixed applications.

Additional benefits from fiber optics include a relatively short signal-delay time, dissemination of cabling along existing (co-axial) paths, and greater security than either radio or satellite transmissions. The capacity of fiber-optic technology has been doubling annually for the past decade, and will continue to increase through the end of this century. Such improvements--the result of new plastics, reduced fiber impurities, and improved fiber-splicing techniques coupled with breakthroughs in new lightwave technology--could eventually bring fiber-optic transmission technology to its physical limit of 10^9 mbps per kilometer [Office of Technology Assessment, 1985]. By the year 2000, speeds of ten gigabits per second on a single fiber seem attainable [Kahn, 1987].

Networked computer architectures will need transmission rates of this order of magnitude to accomplish the types of functions necessary for

sophisticated simulation. A computer terminal with color 1000 X 1000 resolution, transmitting at 30 frames per second, requires 480 megabits per second of network transmission speed. Bigger displays (e.g., four feet square) could increase transmission requirements by another two orders of magnitude in real-time situations, even with data compression. The cost of these large, flat-panel monitors is dropping steadily, although the required number of edge connectors makes quantum leaps in performance difficult. Which of the competing technologies (e.g. plasma, crystal) will dominate is still uncertain.

Satellite telecommunications, the other major factor in increasing transmission capacity, experienced rapid growth in the 1970's, as business and military use flourished in the United States and the Soviet Union. Internationally, access to satellite technology is made available to nations through the International Telecommunications Satellite Organization (INTELSAT).

Satellite communication is accomplished by transmission of high-frequency (C and Ku band) radio transmission to geosynchronous satellites in orbit some 22,300 miles above the earth. The use of this technology has increased rapidly over the past 20 years, as improvements in satellite channel capacity (through better antenna structures, power amplifiers, and low-noise filters coupled with space-proven prime satellite power systems) have expanded transmission capacity and improved reliability. Expected improvements in bit rates and growth in capacity over the next ten years are as shown on Exhibits 2.6 and 2.7.

EXHIBIT 2.6

SATELLITE SYSTEM BIT RATES

* 56 kbps for data systems
* 1.544 or 2.048 mbps for data channels
* 6.44 or 8.448 mbps for high-speed data channels
* 16, 32, and 64 kbps for voice channels
* 1.544 or 2.048 mbps for one-way video conferencing
* 56 or 64 kbps for freeze-frame video

Source: [Kay & Powell, 1984]

EXHIBIT 2.7

GROWTH IN SATELLITE CAPACITY
(Equivalent 40-MHz Transponders)

Year	World	United States
1980	426	156
1985	1,410	478
1990	3,100	756
1995	5,580	1,135
2000	9,870	1,655

SOURCE: IEEE Communications, May, 1984

Continued improvements in multi-beam satellite antennas, on-board satellite switching, high-frequency/high-power systems, with lower-cost earth stations will further contribute to the growth in satellite communications.

The use of satellites in communication systems is expected to continue through the end of the century; however, the rate of growth is subject to a number of technological and economic variables arising through competition from fiber optics. Satellite communications has several inherent characteristics that make fiber-optic cabling a more appealing alternative. The effects of external influences, such as electromagnetic disturbances and weather on satellite communication, cost factors, security issues, and technological complexity may cause

land-based fiber optics to dominate communications systems in the future.

Satellites are dependent on complex underpinning technologies such as launch vehicles and space-based propulsion and power systems. The economics of fiber optics are expected to equal and exceed satellite systems, with the possible exception of very long-haul communications, since transmission cost via satellite is nearly invariant with distance, while the same via cable is not. Even the long-haul economies of satellites over cable are questionable: while transmission cost for cable does increase with distance, it does not increase proportionally for long cables.

Increasing Connectivity and Integration

A second major technological trend in telecommunications is the development and implementation of standards. Two examples are the Open Systems Institute (OSI) seven-layer model (a hierarchical structure of communicating-peer protocols which sets future standards for hardware and software) and the Integrated Services Digital Network (ISDN), envisioned to be a digital, global, public communication network that standardizes digital communication interfaces (facilitating future connectivity of communication networks regardless of geographic location and vendor). This very high bit-rate telecommunications transport system encompasses personal message services, facsimile, teleprinting, computer-to-computer transmission, word processing, information retrieval, monitoring, transactions and teleconferencing [Kay & Powell, 1984].

Initial standards for connectivity created through the development of the OSI Seven-Layer Model and the ISDN have just begun to emerge in the form of hardware and software technology. By the mid-1990's, a significant proportion of

computing and telecommunications systems from major vendors will have implemented these voluntary connectivity standards. By the end of the 1990's, when OSI standards are expected to be mature, the majority of computing systems and telecommunication networks should be in advanced stages of implementation.

In summary, telecommunications are expected to continue rapid growth from the perspective of both speed and capacity. The dominant transmission technology through the end of the 1990's will be fiber optics, which will be used for metropolitan, domestic long-haul, and transoceanic transmission. Fiber optics is replacing co-axial and twisted-pair copper cable and is becoming more competitive than satellite systems, the next most prevalent communication system to be employed through the end of the century. Ground-based microwave transmission and FM radio communication (cellular radio) will continue to be used for selected applications.

Emerging world standards for digital communication networks and computing systems will foster growth, as historically domestic economies expand to global markets and become more reliant on voice- and information-processing technology. Current trends can be expected to create the following impacts:

a merging of telecommunications and computer technology into one comprehensive architecture
dramatically improved connectivity of information technology within multi-vendor environments
increased technological obsolescence due to rapid technological evolution of hardware and software
increases in the range of services and capacity for telecommunications media

More efficient production and longer system lifecycles will result in decreased cost.

Hardware Integration and Long-Range Evolution

One barrier to information technology utilization has been incompatibilities among different devices. The difficulties entailed interconnecting computers, peripherals, and telecommunications systems can be staggering. However, the situation is slowly improving for three reasons. First, emerging generations of computers are sufficiently powerful to emulate each other: for example, a software program now allows a Macintosh II to run IBM PC compatible applications. Second, standardization efforts are gradually creating protocols for allowing devices to work together.

Third, and most important, computers and telecommunications will gradually merge into "synthesis technologies." The increasing universality of digital code and the decreasing cost of powerful processors allow any device to have embedded microchips dedicated to interconnecting with other media. Within a generation, the distinction between computers and telecommunications is likely to be obsolete, and building a network of devices from different vendors will no longer be a major challenge.

Even with current technology, new types of interconnections are emerging. For example, a device is now available which allows a microcomputer to accept high-resolution video input at thirty frames per second and store that data digitally in real time. This will facilitate linking of computers to inexpensive, charge-coupled video camcorders and opens up a broad spectrum of possible mixed-media applications.

Synthesis technologies are also evolving in peripheral devices. For example, laser printers are gradually

dropping in price with expanded capabilities, and seem likely to replace competing technologies (dot matrix, ink jet, thermal, impact) within the next decade. As a result, the "laser copier" may displace the standard xerographic equipment used now for hardcopy reproduction. Such a device would combine an optical scanner, RAM storage, and a laser printer to eliminate the mechanical collator. A series of pages could be scanned in and printed out already collated, since all copies of a particular page no longer need be made at the same time.

These types of technologies are accompanied by decreased cost. For example, the wholesale price of optical scanning elements capable of three hundred dots per square inch resolution has dropped from two thousand dollars each in 1983 to seven dollars. Hand-held copying devices (which output a strip of tape that can be inserted later into a laser printer to produce hardcopy) are beginning to appear in response. Twelve hundred dot per square inch scanners, which will empower devices competitive with typesetting, are expected in the next few years.

As a long-range issue, in about fifteen years the limits of electronics as a substrate for information technology are likely to be reached. The speed of light forces the size of faster computers ever smaller (for example, since electricity travels about fifteen centimeters in a billionth of a second, devices that switch at that speed cannot exceed that size). At dimensions this small, with the number of components per chip exponentially increasing, the heat generated by entropic effects from hundreds of millions of transistors rapidly switching in a tiny volume poses profound dissipation problems. Also, when extremely small distances separate different channels in a chip, quantum mechanical

"tunneling" of electrons from one channel to another--regardless of the insulating properties of the intervening material--creates severe packaging difficulties.

Therefore, while improvements in parallel processing and software engineering may continue to increase the effectiveness of electronic devices, further rapid advances in power and economy for linear, sequential architectures will require a shift to some alternative medium (probably optical or biological in nature). Purely optical computers have theoretical limits about three orders of magnitude faster than electronic devices, and laboratory work with "transphaser" crystals capable of amplifying laser light emissions is underway [Abraham, Seaton, & Smith, 1983]. Major challenges involve developing, on a purely optical level, equivalents to electronic capabilities for random access memory, read only memory, multiplexing, etc. Advances in optoelectronics are behind much of the progress currently being made, but what barriers may later be encountered are currently uncertain.

As an alternative, current research in genetic manipulation may lead to the construction of "biochips," which would contain transistors as small as individual molecules [Drexler, 1986]. Such a development would be possible using tailored enzymes and variations on monoclonal antibodies to deposit three-dimensional patterns of semiconducting materials [McAlear & Wehrung, 1984]. The resulting chip (nanotechnology) might be composed primarily of organic compounds and could conceivably use neural networks similar to those in the human brain as its primary processing architecture.

Whether or not such exotic information technologies are feasible, developments over the next several decades are likely to yield the equivalent of today's

supercomputer power at desktop computer prices. This evolution will result in a vast array of new applications [Office of Technology Assessment, 1985]. For example, a problem that takes one and one-half years to solve on a current microcomputer could be completed in fifty hours. A calculation requiring four days would take thirty minutes; a six-minute problem, less than two seconds. Moreover, the power to implement emerging functionalities in knowledge representation, user interfaces, and computer-supported cooperative work will be inexpensively available.

CHAPTER 3

TECHNOLOGY-RELATED OCCUPATIONAL DISPLACEMENT AND TRAINING NEEDS, ESPECIALLY AMONG WOMEN AND MINORITIES

By:

Karla M. Back and O. W. Markley

CONTENTS

Introduction..... 1

Technology and Job Displacement..... 1

Technology Change as a Cause of Displacement..... 6

Other Causes of Displacement..... 7

Costs of Displacement..... 9

Impacts on Women and Minorities..... 12

Implications for Occupational Education..... 19

Recommendations..... 23

Conclusions..... 24

References..... 26

FIGURES AND TABLES

Figure 3.1 Number of Workers Displaced..... 3

Figure 3.2 Percentage of Displaced Workers and Percentage of Labor Force by Occupation..... 4

Figure 3.3 Percentage of Labor Force and Percentage of Displaced Workers by Region..... 4

Figure 3.4 Control Network for a Semiautomatic System..... 8

Table 3.1 Employment Status of Displaced Workers by Industry of Last Job..... 10

Table 3.2 Employment Status and Area of Residence of Displaced Workers..... 11

Table 3.3 Women's Share of Labor Force..... 14

Table 3.4 Employment Status of Displaced Workers by Age, Sex, and Ethnic Origin..... 15

Table 3.5 Employment in Clerical and Other Administrative Support Occupations..... 16

Table 3.6 Displaced Workers, Weeks Without Work Since Job Loss..... 18

Figure 3.6 The Technology Life-Cycle Concept As Applied to Skill Training..... 22

CHAPTER 3

TECHNOLOGY-RELATED OCCUPATIONAL DISPLACEMENT AND TRAINING NEEDS, ESPECIALLY AMONG WOMEN AND MINORITIES

Introduction

Today, unlike no other time in our country's history, technology is serving as a driving force of change throughout our society. Of particular interest within this study are the affects of technological change on the nature and availability of work. These changes take many forms and directly, as well as indirectly, affect the nature of work in our country.

This paper has three objectives. The primary one is to define and become familiar with job displacement and technology-related changes in occupations. A second is to explore causes of job displacement, and costs of technology-related job displacement. The third objective of this paper is to address considerations and options for the future, accepting the notion that technology will continue to be a major driver of our job market and occupational changes now and in the years to come. In particular the effects of this displacement on women and minorities will be addressed.

Technology and Job Displacement

What is technology? In the broadest sense of the word, technology "includes the physical devices -tools, instruments, machines, appliances--used to perform a wide variety of tasks; the whole body of technical activities that people engage in to perform the tasks--skills, methods, routines, procedures; and varieties of social organization, in factories, offices, stores, and workshops" (Winner,1977). In a narrower sense, technology often is used to mean the apparatus or physical devices of performance. In our use of technology and its implications for

the workforce, we are using the broader definition, because we are interested in the "activities of people, and the way their activities are combined with materials and the physical apparatus in large-scale systems" (OTA, 1986, p.322).

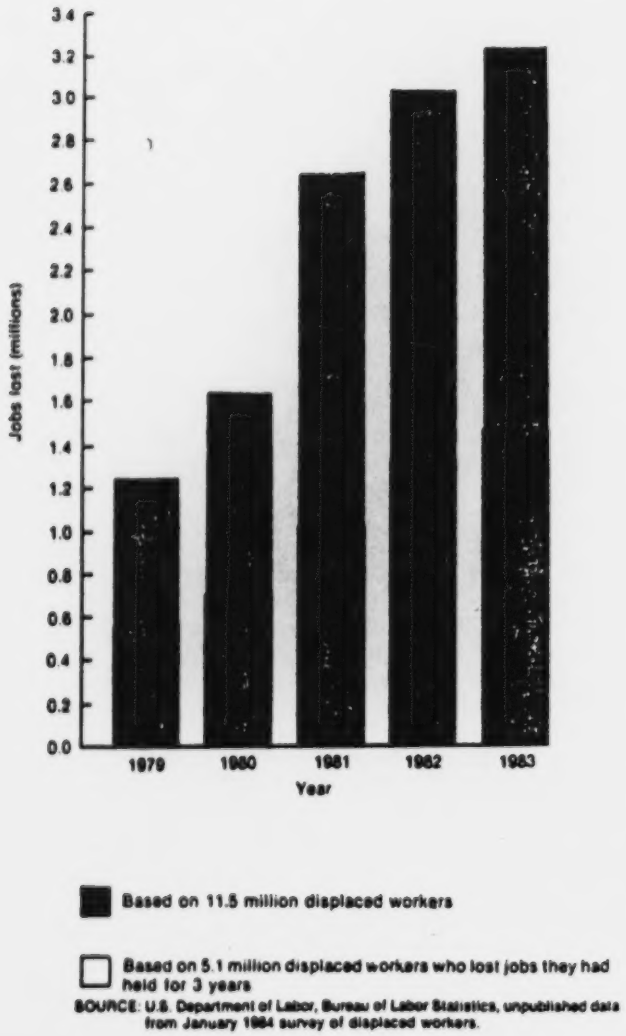
Displacement of workers due to technological changes includes any adult with an established work history who has lost their job through no fault of their own, and who could face real difficulty in finding a new one due to technological innovations and change (OTA, 1986, p.105).

Recent statistics from the United States Bureau of Labor Statistics indicate several alarming trends that add light to this picture of job displacement:

- From 1979 to 1984, 11.5 million American workers lost jobs because of plant shutdowns or relocations, rising productivity, or shrinking output often caused by technological changes (see Figure 3.1).
- Of those out of work who found new jobs, over half took a cut in their earnings (see Figure 3.2).
- Displaced workers are typically white males of primary working age with a steady history in a blue-collar job in the Midwest or Northeast although the numbers of women and minorities are on the increase.
- The most overrepresented occupational group by far were machine operators, assemblers, and repairers.
- Manufacturing workers experienced job losses far out of proportion to their numbers.
- The hardest areas hit geographically were the Great Lakes Region--Michigan, Ohio, Indiana, Illinois, and Wisconsin (see Figure 3.3).
- Displaced workers are likely to experience prolonged unemployment; 43% are out of work on the average of 27 weeks.
- Displaced manufacturing workers will increasingly have to find new employment in the service sector industries.

(U.S. Department of Labor, BLS, 1985)

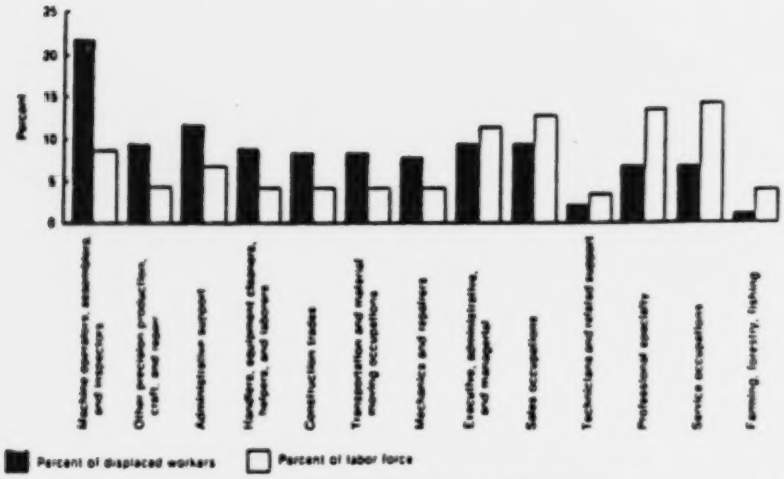
FIGURE 3.1
NUMBER OF WORKERS DISPLACED, 1979-1983



Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

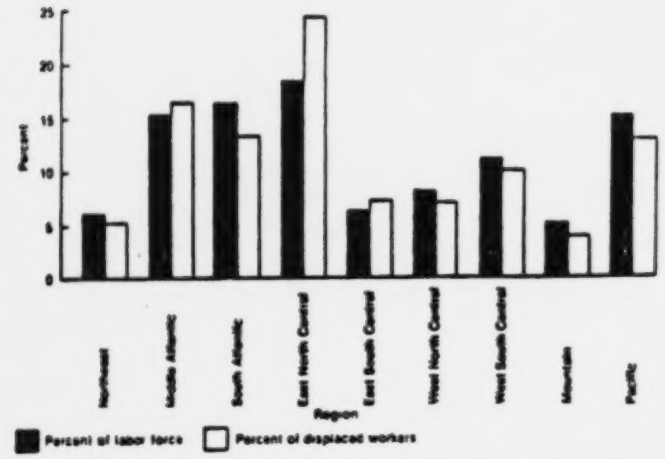
FIGURE 3.2

PERCENTAGE OF DISPLACED WORKERS
AND PERCENTAGE OF LABOR FORCE BY OCCUPATION



SOURCE: U.S. Department of Labor, B.L.S. *Employment and Earnings*, January 1985, and Paul O. Flaim and Ellen Sehgal, "Displaced Workers of 1979-83: How Well Have They Fared?" *Monthly Labor Review*, June 1985, p. 7.

FIGURE 3.3
PERCENTAGE OF LABOR FORCE AND PERCENTAGE OF DISPLACED WORKERS
BY REGION, 1984



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, and unpublished data, and U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earnings*, various issues.

Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

Some examples of these changes include workers such as secretaries who find their experiences and skills less useful as new technological systems are introduced to replace previous people skills. Or the salesperson who finds himself out of a job because technology offers automated systems which take and process orders for customers. In certain instances these individuals may learn new skills to operate this technology, but as we will explore later, there will be a need for fewer operators of these technologies, which then produces additional displacement of workers.

Our nation's factory workers are finding their previously secure positions as production workers are now at risk. More advanced skilled workers are now in demand in many occupations including manufacturing, maintenance services, and other blue-collar positions. Positions including the shipping or moving of materials, as well as white-collar data entry jobs are also at risk.

On the upside of technological change is the creation of new products, new markets, and new jobs. These new technologies have in many ways created new industries such as electronics which then generate thousands of new worker positions. These positions will require trained or retrained workers in state-of-the-art systems and application understanding of these new technologies. Additionally, these innovations create new work environments which are an additional change which must be addressed.

The downside of these technological changes is that it causes significant affects on both the availability of jobs as well as the type of jobs and workers needed. The balance of supply and demand also come into play in the picture. Unless demand and output are rising faster than labor productivity, jobs will be lost (OTA, 1986, p.321).

Two groups who are particularly vulnerable to such displacement are women and minorities. With forecasts predicting continual development of technology and increasing numbers of women and minorities joining the workforce, the phenomenon of job

displacement will continue to grow--and the challenge of how to handle job displacement for women and minorities will become an increasingly important economic, social, and political issue as well.

Technological Change as a Cause of Displacement

Although technological change alone does not decide on the makeup or nature of jobs, it does play an increasingly strong role in determining the focus and likely movement in the avenues that occupations will move to in the future. Technology affects the job market in three different ways: (1) to displace tasks previously performed by people; (2) to create new tasks; and (3) to limit, by it's inherent features, the ways in which tasks can be assigned to workers (OTA, 1986, p.337).

Examples of the first affect, displacement of tasks for people to do, might include robots which now load tools onto automated systems which totally bypasses the need for a human, and yet the task still exists. Another example is the change in process or product which eliminates the task completely. Thus, printing and precision machine skills were no longer needed because the process has been virtually eliminated.

A more common example is in the nature of work and how it is restructured. Work that once took five lawyers or accountants, now with automated offices and search systems, often takes only one or two. This leaves fewer people needed to complete the same number of complex tasks.

Still another example is that of new technologies which create tasks such as automated material handling which do away with driving a delivery cart as well as loading and unloading. In completing the automation process, computer programming, machine monitoring, and maintenance are being displaced by computers and robots.

There are always limits to replacing human labor completely with the emerging technologies. There are three specific influences which should be considered in relation to human beings

and machine use. These include: (1) technological constraints; (2) the need for design, implementation, maintainance, and repair technology; and (3) selection of some tasks for people to perform because of their importance to the quality of life, tradition, or aesthetics.

Tasks will change as there is more sharing by workers and computers, and in turn, people will share tasks such as manipulation or observation with sensors and mechanical actuators. Since these tasks are much more suitable to transference to machines than others these positions will be increasingly vulnerable to displacement.

An example of a combined approach (man and machine) is shown in Figure 3.4, Control Network for a Semiautomatic System. The concept of a combined man/machine approach offers an alternative to traditional displacement patterns. As we pointed out earlier, technology and displacement certainly involve human beings and these decisions affecting human resources will play a key role in how technology-induced job displacement will affect the nature of work and jobs.

Other Causes of Displacement

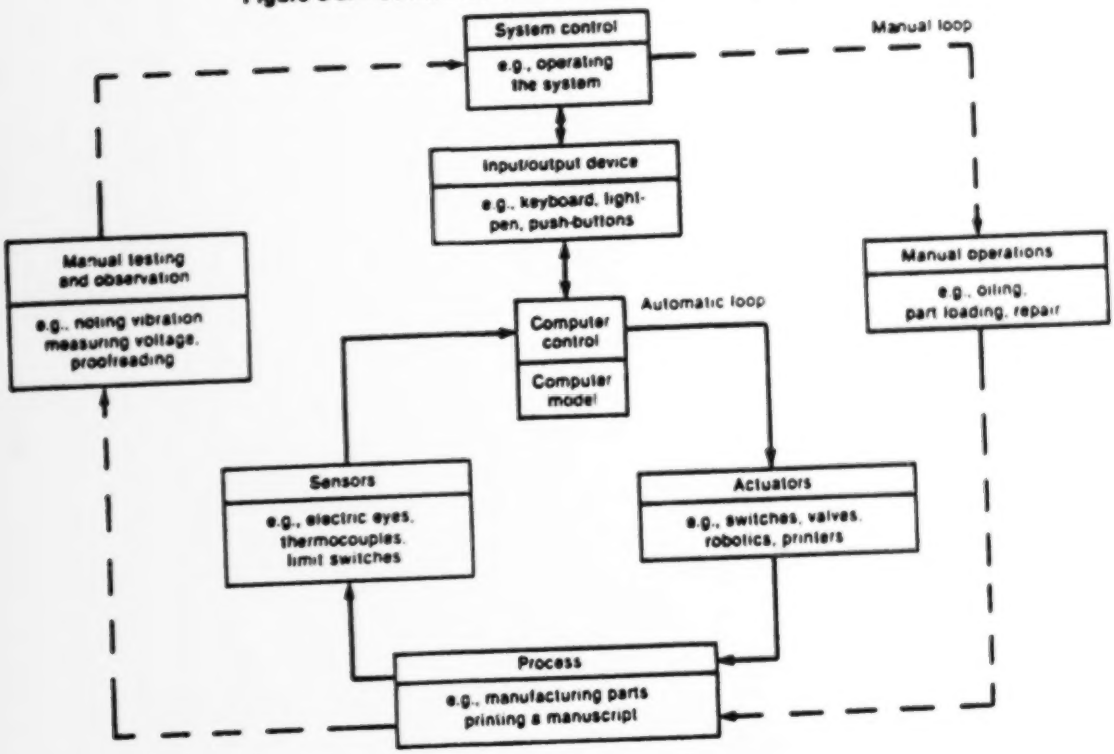
The causes of displacement are complex and numerous. We have predominately focused on displacement caused by technological change but there are other causes as well. International competition can bring about changes in the need for workers. Losses and gains in the international markets of trade can cause major shifts in economic balance which in turn affect employment needs, types of jobs, and people being displaced as a result.

As the United States becomes less competitive internationally, the number of companies employing workers drops, which results in displacement of these workers. Industries such as apparel and accessories, textiles, shoes, and steel were greatly affected in the 1970's with this trend (Bayard,1980). In analyzing the products we now import into our country, or have

FIGURE 3.4

CONTROL NETWORK FOR A SEMIAUTOMATIC SYSTEM

Figure 8-6.—Control Network for a Semiautomatic System



Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

partial production done in other countries, one can see the shifts in the production of apparel, textiles, and shoes as simply one example. Based on recent import and export figures, this trend will continue throughout the 1980's-1990's (BLS,1985).

A third, and more indirect cause of displacement is the changing consumption patterns by Americans. As we change our preferences and tastes, consumption changes and as the new products are introduced, the old ones are often discarded. Examples of these consumption shifts by Americans include the adding machine which is being replaced by calculators; horses being replaced by the automobile; and often hand calculators being replaced by the microcomputer. Although consumers continue to spend more money, and personal expenditures have risen, growth in productivity exceeded growth in demand for many products, thus creating displacement (Haggard, 1985).

Costs of Displacement

Costs of displacement in the workforce can be studied from both personal and social cost perspectives. Examples of personal costs include unemployment as seen above in Table 3.1 - Employment Status of Displaced Workers by Occupation of Lost Job, January 1984.

A second major cost of displacement is lower pay and lower status for workers than they had in previous positions. The average range of lower pay for new positions ranges from 9% to 41% loss in earnings. Blue-collar semiskilled and unskilled workers suffer the greatest losses in earnings (Flaim and Sehgal,1985). Table 3.2 delineates the employment status and area of residence in January 1984 of displaced workers.

Loss of benefits, especially pensions and health benefits, are of particular concern. Early retirement and relocation are considered options available to some workers. Mental and physical stress often takes its toll as well for many workers and their families.

TABLE 3.1

EMPLOYMENT STATUS OF DISPLACED WORKERS BY INDUSTRY OF LAST JOB, JANUARY 1984

Industry of lost job	Total (in thousands)[a]	Percentage employed	Percentage unemployed	Percentage not in labor force[b]
Total, 20 years and older	5,091	60.1	25.5	14.4
Nonagricultural private wage and salary workers	4,700	59.8	25.8	14.4
Mining	150	60.4	31.0	8.6
Construction	401	55.0	30.7	14.3
Manufacturing	2,483	58.5	27.4	14.1
Durable goods	1,675	58.2	28.9	12.9
Lumber and wood products	81	67.9	19.1	13.0
Furniture and fixtures	65	b	b	b
Stone, clay, and glass	75	47.5	30.5	22.0
Primary metal industries	219	45.7	38.7	15.6
Fabricated metal products	173	62.0	32.2	5.8
Machinery, except electrical	396	62.3	27.4	10.3
Electrical machinery	195	48.2	34.5	17.3
Transportation equipment	354	62.6	26.0	11.4
Automobiles	224	62.9	24.0	13.1
Other transportation equipment	130	62.1	29.4	8.5
Other durable goods	116	b	b	b
Nondurable goods	808	59.1	24.2	16.7
Food and kindred products	175	52.5	32.6	15.0
Textile mill products	80	59.8	26.2	13.9
Apparel and other finished textile	132	63.0	14.2	22.8
Paper and allied products	60	b	b	b
Printing and publishing	103	58.0	22.9	19.1
Chemical and allied products	110	64.0	27.3	8.7
Rubber and miscellaneous plastics	100	62.8	18.3	18.8
Other	49	b	b	b
Transportation and public utilities	336	57.9	26.8	15.3
Wholesale and retail trade	732	61.4	21.6	16.9
Wholesale trade	234	69.6	22.0	8.4
Retail trade	498	57.6	21.5	20.9
Finance, insurance, and real estate	93	78.5	12.4	9.1
Services	506	65.0	20.5	14.5
Agricultural wage and salary workers	100	69.9	22.9	7.2
Government workers	248	63.3	18.7	18.0

[a]Data refer to persons with tenure of 3 or more years in one job, who lost or left that job between January 1979 and January 1984 because of plant closings or moves, slack work, or the abolishment of their positions or shifts.
[b]Data not shown where base is less than 75,000.

SOURCE: Paul O. Flaim and Ellen Sehgal, "Displaced Workers of 1979-83: How Well Have They Fared?" *Monthly Labor Review*, June 1985.

Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

TABLE 3.2

EMPLOYMENT STATUS AND AREA OF RESIDENCE IN JANUARY 1984 OF DISPLACED WORKERS (IN THOUSANDS)

Characteristic	Total	Regional totals (in thousands)								
		New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
Total	5,091	260	794	1,206	426	664	378	484	211	667
Employment status in January 1984:										
Employed	3,058	171	428	621	276	461	209	344	148	399
Unemployed	1,299	48	225	400	96	117	113	85	33	181
Period of unemployment, percentage of unemployed workers:										
Less than 5 weeks	22	[b]	24	21	13	29	17	25	[b]	18
27 weeks or more	39	[b]	37	47	48	26	52	30	[b]	28
Not in labor force	733	41	141	185	54	85	56	55	30	86

[a]Data refer to persons with tenure of 3 or more years in one job, who lost or left that job between January 1979 and January 1984 because of plant closings or moves, slack work, or the abolishment of their positions or shifts.

[b]Data not shown where base is less than 75,000.

SOURCE: Paul O. Flaim and Ellen Sehgal, "Displaced Workers of 1979-83: How Well Have They Fared?" *Monthly Labor Review*, June 1985

Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

The social costs of displacement also affect many communities. New England Mill towns and Appalachian coal regions are just two examples of the communities being affecting by displacement both directly and indirectly.

One theory that has been created is that of the "missing middle " (Bluestone,1983). The displacement of well-paid blue-collar workers from the older, unionized smokestack industries, and the replacement of those jobs by less paying positions is often described as the "declining middle" (Bluestone,1983). Still other analysts do not forecast this as a long-term trend, and believe the causes of earnings to be more a function of demographics and of a temporary nature (Levitan and Carlson,1984). Whichever forecast is correct, the short-term affects are at a minimum costly and at a maximum devastating to many workers and their families, which becomes devastating to our society as a whole.

All experts do agree on one point with regard to this issue. If the technological changes do raise productivity and benefit business and its competitive advantage internationally, but continue to displace workers, we will loose the very "middle class" that this country's values and economics have been built on. With this loss, the very markets that support American industry could decline causing pessimism and lack of fairness, which will in turn cause additional imbalance and loss of stability for our nation (Blackburn and Bloom,1985).

Impacts on Women and Minorities

In reviewing the major studies on the impact of technological change and displacement, the most consistent findings are in the studies of the impact of displacement caused by technological change on women and minorities. Recent projections in a report by the National Alliance of Business entitled, Employment Policies: Looking To The Year 2000, indicate alarming statistics on the increasing number of women and minorities entering the workforce and their increased chances of

displacement. According to the National Alliance for Business report, women will account for two-thirds of the labor force during the 1980's and 1990's (see Table 3.3 on Women's Share of the Labor Force). The information in Table 3.4 displays Employment Status of Displaced Workers by age, sex, and ethnic origins as of January 1985.

Recent insurance industry, as well as other clerical worker, jobs studies indicate with few exceptions, that the consequences from technological change have been mixed, although not ambiguous (Feldberg and Glenn, 1983). There is limited empirical data or longitudinal work which has been published on this specific demographic group, but studies conducted in the insurance and clerical-related fields offer the most pertinent information for our purposes. In Table 3.5, 1984 national employment averages of clerical and other administrative support personnel are highlighted. This table clearly demonstrates the large percentages and vast numbers of women found in these occupational areas. The majority of the findings show that office automation has eliminated or in some cases redistributed many of the more rote tasks in the clerical work area.

There has not been the growth of autonomy or control for these new positions and workers, for the most part. Additionally, opportunities have often been severed, since the elimination of many of these needed positions cuts off the traditional channels of occupational mobility between the clerical world and the management world. What was once a natural channel for women and minorities to move into entry-level managerial positions, is no longer available, or not as frequently, due to the loss of positions and displacement of these workers. According to the Working Women Educational Fund in 1980, the only promotion available when word processing is introduced into a work environment might be supervision of other word processing personnel.

Women, especially minority women, are often the ones who are displaced as a result of these technological changes because they

TABLE 3.3

WOMEN'S SHARE OF LABOR FORCE

	Actual		Projected‡	
	1975-1980	1980-1985★	1985-1990	1990-1995
Labor force growth (000s)	13,165	9,632	6,081	6,515
Women's labor force growth (000s)	8,012	5,560	4,460	4,379
Women's share (%)	60.9	57.7	73.3	67.2

‡Bureau of Labor Statistics
★June 1985

Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

TABLE 3.4

EMPLOYMENT STATUS OF DISPLACED WORKERS BY AGE, SEX, AND ETHNIC ORIGIN, JANUARY 1984

Age, sex, race	Total (in thousands)[a]	Percentage employed	Percentage unemployed	Percentage not in labor force[b]
Total, 20 years and older ..	5,091	60.1	25.5	14.4
20-24 years	342	70.4	20.2	9.4
25-54 years	3,808	64.9	25.4	9.6
55-64 years	748	40.8	31.8	27.4
65 years and older.....	191	20.8	12.1	67.1
Men:				
Total, 20 years and older	3,328	63.6	27.1	9.2
20-24 years	204	72.2	21.7	6.1
25-54 years	2,570	68.2	26.8	5.0
55-64 years	461	43.6	34.1	22.3
65 years and older....	92	16.8	12.9	70.3
Women:				
Total, 20 years and older	1,763	53.4	22.5	24.2
20-24 years	138	67.8	18.0	14.2
25-54 years	1,239	58.0	22.6	19.4
55-64 years	287	36.3	28.0	35.7
65 years and older....	99	24.6	11.3	64.1
White:				
Total, 20 years and older	4,397	62.6	23.4	13.9
Men	2,913	66.1	25.1	8.8
Women	1,484	55.8	20.2	24.1
Black:				
Total, 20 years and older	602	41.8	41.0	17.1
Men	358	43.9	44.7	11.4
Women	244	38.8	35.6	25.6
Hispanic origin:				
Total, 20 years and older	282	52.5	33.7	14.1
Men	189	55.2	35.5	9.3
Women	93	46.3	30.0	23.6

[a]Data refer to persons with tenure of 3 or more years in one job, who lost or left that job between January 1979 and January 1984 because of plant closings or moves, slack work, or the abolishment of their positions or shifts.

[b]Workers may retire from the labor force because of voluntary choice, retirement, or discouragement.

Note: Breakdown data on the ethnic groups will not sum to the corresponding totals because data for "other races" are not presented and Hispanics may be included in both white and black populations. Thus, Hispanics may be counted more than once in the table.

SOURCE: Paul O. Flaim and Ellen Sehgal, "Displaced Workers of 1979-83: How Well Have They Fared?" *Monthly Labor Review*, June 1985.

Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

TABLE 3.5

EMPLOYMENT IN CLERICAL AND OTHER
ADMINISTRATIVE SUPPORT OCCUPATIONS, 1984 ANNUAL AVERAGES

Selected Occupation	Total Employed	Women as Percentage of Total Employed
Total administrative support, including clerical	16,722,000	79.9
Supervisors	647,000	52.9
General office	375,000	64.8
Financial records processing	81,000	65.8
Distribution, scheduling, and adjusting clerks	149,000	22.2
Computer equipment operators	716,000	64.7
Computer operators	713,000	64.7
Secretaries, stenographers, typists	4,877,000	97.7
Secretaries	3,935,000	98.3
Stenographers	58,000	86.6
Typists	885,000	95.7
Information clerks	1,250,000	88.9
Interviewers	181,000	86.2
Hotel clerks	78,000	71.8
Transportation ticket and reservation agents	97,000	59.9
Receptionists	665,000	96.9
Records processing occupations, except financial	847,000	82.1
Order clerks	185,000	79.0
Personnel clerks, except payroll and timekeeping	64,000	90.6
File clerks	298,000	82.6
Records clerks	186,000	81.7
Financial records processing	2,452,000	90.0
Bookkeepers, accounting, and auditing clerks	2,010,000	91.2
Payroll and timekeeping clerks	176,000	84.8
Billing clerks	146,000	87.2
Cost and rate clerks	81,000	78.1
Duplicating, mail and other office machine operators	72,000	69.8
Communications equipment operators	234,000	92.0
Telephone operators	226,000	92.8
Adjusters and investigators	685,000	70.6
Insurance adjusters, examiners, and investigators	306,000	68.1
Investigators and adjusters, except insurance	319,000	72.2
Eligibility clerks, social welfare	71,000	89.5
Bill and account collectors	93,000	65.1
Miscellaneous administrative support	3,531,000	85.1
General office clerks	664,000	80.9
Bank tellers	488,000	91.4
Data entry keyers	351,000	91.3
Statistical clerks	95,000	75.8

Source: U.S. Department of Labor, Bureau of Labor Statistics, "Employment and Earnings," January 1985.

Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

BEST COPY AVAILABLE

are highly represented at the entry-level clerical positions that are vanishing. Minority women make up almost one-fourth of all women file clerks and more than one-fifth of all women employed as office machine operators, typists, telephone operators, and stenographers (Department of Labor,1985).

The telecommunications industry is a good example of this. Over 70% of the minority women found in this industry are represented in office or clerical positions, including a large number of switchboard operators who are being phased out by automated telephone equipment. If one examines this situation even closer it becomes even bleaker. Within race and class there is still another perspective. The lowest-level clerical jobs are those with the highest number of minority women. These positions are often eliminated not simply de-skilled, so these people cannot simply retrain, because there is no position to retrain for.

Still another concern for minority women is the innovation of the electronic communications technology which makes it possible for employers to move clerical workers away from traditional worksites such as the inner cities, or downtown areas, where many of the minority employees live. Relocations include white suburbs, rural areas, and Third World countries (often labeled "offshore"). This relocation activity could present problems with transportation and childcare, to name only two.

White women who were represented with higher educational levels will probably benefit the most from the upgrading or new clerical positions, if one can call it a <u>benefit.</u> They will probably continue in low-paid, dead-end positions, with virtually no opportunities for advancement (Baran and Teegarden, 1984).

The Bureau of Labor Statistics indicates that from 1979 to 1984 over one-third of adult workers displaced were women. The period of recovery time (locating another job) is longer for women, 26 weeks for a women versus 22 weeks for a man. In looking at Figure 3.6 the story of time and displacement becomes clearer.

TABLE 3.6
DISPLACED WORKERS, 1979-1983:
WEEKS WITHOUT WORK SINCE JOB LOSS (IN THOUSANDS)

	Total[a]	Weeks without work since job loss				
		Less than 5	5-26	27-52	More than 52	Median number of weeks
Total	5,091	1,173	1,619	983	1,211	24.1
Men	3,328	766	1,115	644	732	21.8
Women	1,763	407	504	339	479	26.3

[a]Data refer to persons with tenure of 3 or more years in one job, who lost or left that job between January 1979 and January 1984 because of plant closings or moves, slack work, or the abolishment of their positions or shifts

SOURCE: Paul O. Flaim and Ellen Sehgal, "Displaced Workers of 1979-83: How Well Have They Fared?" *Monthly Labor Review*, June 1985

Source: U.S. Congressional Office of Technology Assessment, Technology and Structural Employment: Reemploying Displaced Adults. Washington, D.C.: U.S. Government Printing Office, 1986.

A recent report released by the AFL-CIO Committee on the Evolution of Work addressed the relationship among unemployment, changes in the workforce, displacement, and technology. The report then goes on to suggest that if the present course continues unchanged, this country in the 1990's will develop a two-tier workforce:

> "At the top will be a few executives, scientists, engineers, professionals, and managers, performing high-level, creative high paid full-time jobs in a good work environment...At the bottom will be low-paid workers performing relatively simple, low-skill, dull, routine, high-turnover jobs in a poor work environment...Between these two tiers will be fewer and fewer permanent, well-paid, full-time, skilled, semi-skilled, and craft-production and maintenance jobs which in the past have offered hope and opportunity and upward mobility to workers who started in low-paid, entry-level jobs."

The report goes on to envision that given the current status of minorities in the U.S. workforce we may also see a gap based on race and ethnicity with minorities primarily relegated to the bottom tier of the workforce, first to be displaced, with little

or no opportunity for upward mobility (Malcom, 1985).

The implications of displacement for women and minorities because of technological change are numerous and complex. Many of the implications are intertwined with other social and economic factors which must be considered. There is also the trickle down affect in looking at this picture. One must consider short-term and long-term affects from this displacement, recovery time needed to locate a new job, loss of wages, costs for family expenses, childcare issues, and quality of life, to name only a few.

Implications for Occupational Education

Given that job displacement will continue to be associated with technological innovation in the workplace and that there will be disproportionately great job displacement among women and minorities, what should this imply for technical, vocational and adult education?

Until relatively recently, most people assumed that a major consequence of the "high technology revolution" would be the demand for higher skill levels among the workforce. If correct, this would imply that training to increase skill levels will be needed, especially for displaced workers. During the mid-1980s, however, evidence began to mount that the introduction of high technology innovations into the workplace often tends to bring about a general "de-skilling" of requirements, due to the increased power and "user-friendliness" of the new technologies as compared to what they replaced; and that as a result there would be an overall decrease rather than an increase, on the training demand for higher skill levels (Rumberger, 1984; Levin and Rumberger, 1987; Marshall, 1987). For instance, compare the skills required to operate the semi-automated checkout equipment Safeway, as contrasted with those of memorizing produce price changes on an almost daily basis.

Something of a debate has arisen as to whether the aggregate trend is toward higher skill levels or toward deskilling. The

one comprehensive review of this literature which examines this question (Spenner, 1985), determined that which conclusions are reached depends on how the data are gathered and analyzed: studies which use aggregate data collection methods tend to support the view that more skills are needed by workers today; those that use case study methods tend to find that deskilling is more common.

More recently it has been suggested that educators should not get hung up on the question of whether the overall past effects of new technologies have required more or less skills in the workforce, but rather on how new technologies should be developed in the future (Back, et al., 1987; Zuboff, 1988). These authors note that new technologies which are designed to promote labor saving automation will surely result in an aggregate deskilling and a decrease in the quality of worklife generally, while technologies that customize high technology capabilities to enhance labor effectiveness result in aggregate skilling, as well as increased quality of work life. The fact that leaders in the field of educational technology can play an important role in deciding which of these two scenarios is followed is certainly an important, albeit a long-range, implication of this analysis.

In the shorter-term, for purposes of macro-level forecasting and planning of vocational education (e.g., individual states and the country as a whole), one must observe that both increases and decreases in overall skill level have been and will continue to be produced by new technologies--with a preponderance of upskilling for some populations and deskilling for others (Marshall, 1987). And because women and minorities so frequently find only the less desirable jobs available to them, deskilling will affect them disproportionately.

Flynn (1988, p. 67) has documented this phenomenon with regard to gender discrimination:

"Although 'emerging' occupations had no gender

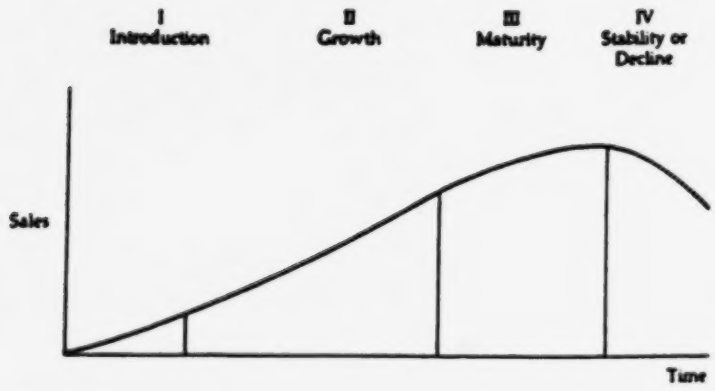
stereotype before they were filled, the better, higher-skill positions were almost exclusively staffed by males. In contrast, females staffed the new, lower-skill jobs."

For purposes of forecasting and planning at a more micro-level (e.g., individual PSIs and the state as a whole), a good model through which to examine these differences, is an analog of the production life cycle (Flynn, 1984; 1988).

Take a look at Figure 3.6. Its upper part shows how a given new product or technology application grow, peaks, then declines as it is replaced by a yet newer application. This "product life cycle" phenomenon is frequently used as a basis for strategic planning. The lower part of Figure 3.6 illustrates how the life cycle concept can be used for planning of occupational education. Through use of needs assessments (both current needs and those that are forecasted to emerge), leaders of economic development and occupational education in a given region can "map" how and where different types of training should be produced and delivered at different stages of a given technology they know will soon be important for their region--as well as those that will be declining. It is a model that could help regional leaders better visualize, and hopefully deal with, the difficult problem of job displacement and retraining.

FIGURE 3.6
THE TECHNOLOGY LIFE CYCLE CONCEPT AS APPLIED TO SKILL TRAINING

The Product Life Cycle



Characteristic	Phase			
	I	II	III	IV
Product	Variable; often custom designs	Increasing standardization		Mostly undifferentiated; standardized
Product innovation	Frequent experimentation; major changes	Declining rate		Minor refinements, if any
Volume	Small-scale	Rising volume	Large scale	Large scale
Process	Job-shop; batch production	Increasingly automated	Capital-intensive mass production	Capital-intensive mass production
Process innovation	Exploratory	Relatively high rate; major innovations	Rate declines	Minor refinements, if any
Equipment	General purpose	Increasingly specialized		Special purpose

The Skill-Training Life Cycle

	Phase			
	I Introduction	II Growth	III Maturity	IV Stability or Decline
Tasks	Complex	Increasingly routinized		Segmented
Job skills	Firm-specific	Increasingly general		General
Skill training provider	Employer or equipment manufacturer	Market-sensitive schools and colleges	Schools and colleges more generally	Schools and colleges; some skills provided by employers
Impact on job structures	Job enlargement; new positions	Emergence of new occupations		Rigid job hierarchy with formal education and occupational work experience requirements

Source: Flynn, P. Facilitating Technological Change: The Human Resource Challenge. Cambridge, MA: Ballinger, pp. 12 & 19, 1988.

Recommendations

The following policy initiatives are recommended for consideration as ways in which the system of vocational, technical, and adult education in Texas could respond to the challenges noted above:

1. Increased awareness on the part of deans and directors to become more responsive to the external needs of the business community and adapt flexibility. Needs assessments should be ongoing to develop this responsiveness.
2. Knowledge of competency levels within all programs is vital for deans and directors so that they can respond to emerging education and training needs.
3. Further research looking into methods for coordinating the identification and targeted displacement of groups for retraining as a result of technology-induced job displacement.
4. State-wide coordination of activities surrounding occupations or job clusters targeted for technology-related job displacement for likely job-retraining needs (SOICC).
5. Increased funds spent state-wide for awareness and vocational/career decision-making and counseling for women and minorities.
6. Annual estimate by region on a state-wide basis of technology-induced job displacement.
7. Annual funding for community colleges and technical institutes to sponsor regional forums with business/industry and community leaders on potential displacement projections/activities/retraining of/for the future.
8. Further research into organizations in Texas who are innovative in their approach to job displacement and retraining.

Conclusion

There is little question that technology is and will continue to serve as a major influence on the nature of work. What is less than clear is how it will influence the work force in the future and to what degree. It is fairly certain that the causes of displacement, technological innovations, increased international competition, and changing patterns of Americans consumption, will if anything continue to expand and change.

These technological, political, economic, and social factors will continue to influence both the nature of work and the number of jobs available. Indirectly, some of these factors can be controlled in a limited fashion, but for the most part these are uncontrollable changes which are emerging within our workforce today and in the future.

The picture of the damaging short-term and long-term affects technological change as a cause of displacement has on women and minorities is only now beginning to emerge. This issue of employment for these Americans will become an increasing challenge as the differences in jobs, types of positions, and opportunities available become even more evident. If woman are to become two-thirds of the workforce in the 1990's, the challenge of what to do, how to effect a change, and repercussions of this will become a policy issue in the very near future.

Job displacement by itself is an issue that must involve training and retraining. Technology-induced job displacement creates an additional challenge for educators. Federal, state, and local officials are beginning to address these training and retraining needs through programs such as the Adult Education Act (AEA), which contributes nearly half of the funds States and localities spend for adult basic education. With support from the Carl D. Perkins Vocational Education Act enacted in 1984, the states should be targeting monies to assist in paying for training and retraining programs. Under Title III of the Job Training Partnership Act (JTPA) displaced worker projects are funded for training and retraining for emerging technologies and

new positions. JTPA provides the displaced worker services as soon as the layoff or displacement begins.

Various countries are choosing different strategies in attacking this problem of worker displacement, training, and retraining needs. Many of the European models as well as Canada's Model (IAS) require mandatory advance notice to workers. Additional interventions these models include are outplacement services, retraining, and new job placement. What is crucial is that we create a plan and try to respond in this fashion, instead of reacting to the reality of technology-induced job displacement. Technology and displacement are becoming a very real part of our work environments in the U.S. We certainly have choices as to how we decide to plan and respond to the needs of our nations's present and future workers. These choices are crucial to the present and future of our economy and society, as well.

REFERENCES

Trend Analysis Program. The Changing Workplace: Perceptions and Reality. Washington, D.C.: American Council on Life Insurance, March, 1984.

Blackburn, M., and Bloom, D. "What is Happening to the Middle Class?" American Demographics, January, 1985.

Bluestone, B. "Industrial Dislocation and Its Implications for Public Policy," a paper prepared for the Third Annual Policy Form on Employability Development, Washington D.C., 1983.

Bureau of Labor Statistics, U.S. Department of Labor, Employment and Earnings, September, 1985.

Feldberg, R. and Glenn, E. "Technology and Work Degradation: Effects of Office Automation on Women Clerical Workers." Pp.59-78 in Joan Rothschild (Ed.), Machina Ex Dea: Feminist Perspectives on Technology. New York: Pergamon, 1985.

Flaim, P and Sehgal, E. "Displaced Workers of 1979-1983: How Have They Faired?" Monthly Labor Review, June 1985.

Flynn, P. "Production Life Cycles and Their Implications for Education and Training." Final Report, Grant No. NIE-G-82-0033. Washington, D.C.: National Institute of Education, 1984.

Flynn, P. Facilitating Educational Change: The Human Resource Challenge. Cambridge, Mass: Ballantine, 1988.

Hunt, A. and Hunt, T. A Critique of "The Impacts of Automation on Employment, 1963-2000" by Wasily Leontief and Fay Duchin. Kalamazoo, Mich: The W. E. Upjon Institute for Employment Research, 1984.

Kraft, P. and Dubnoff, S. "The Division of Labor, Fragmentation, and Hierarchy in Computer Programming. Paper presented to the meetings of the Eastern Sociological Society, Boston, Mass: 1984.

Levin, H. and Rumberger, R., "Educational Requirements for New Technologies: Visions, Possibilities, and Current Realities," Educational Policy, Vol. 1, No. 3, 1987.

Levitan, S., and Carlson, P. "Middle Class Shrinkage?" Across the Board, October 1984.

Malcom, S. "The Place of Minorities in the Scientific and Technical Workforce," The Black Scholar, October 1985.

Murphree, M. Women and Office Automation: Issues for the Decade Ahead. Written under contract for the Women's Bureau, Department of Labor, 1985.

Marshall, R. Education, Technology, and the Texas Economy: 1987-1989. Austin, Texas: University of Texas, 1987.

National Alliance of Business. Employment Policies: Looking to the Year 2000. 1986.

Nelson, F. "Black Computer Workers: Closing the Gap in High Technology Employment," Journal of Negro Education, Vol. 54, No. 4, pp. 548-557, 1985.

Rumberger, R., The Potential Impact of Technology on the Skill Requirements of Future Jobs. Stanford CA: Institute for Research on Educational Finance and Governance, Report No. 84-A24, 1984.

Spenner, K. "The Upgrading and Downgrading of Occupations: Issues, Evidence, and Implications for Education." Review of Educational Research, 55, pp. 125-154, 1985.

Office of Technology Assessment, U.S. Congress. Technology and Structural Unemployment: Reemploying Displaced Adults. Washington D.C.: U.S. Government Printing Office, 1986.

Virgil, J. "Impact of Technology on the Hispanic Community." Report prepared for presentation to the Mexican American Engineering Symposium, Albuquerque, New Mexico, April 11-13, 1984.

Winner, L. Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought. Cambridge, Mass: The MIT Press, 1977.

Zuboff, S. In the Age of the Smart Maching: The Future of Work and Power. New York: Basic Books: 1988.

CHAPTER 4

PUBLIC-PRIVATE INITIATIVES AS A POLICY OPTION FOR IMPROVING OCCUPATIONAL EDUCATION

By:

Paul C. Fama, Karla M. Back and O. W. Markley

CONTENTS

Introduction..... 1

History..... 2

A Framework for Understanding New Roles that Public-Private Partnerships Might Play in Occupational Education..... 4

Public Hiring Private..... 4

Public-Private Entrepreneurial..... 5

Corporate Giving..... 7

When are Public-Private Partnerships Effective And Useful?..... 8

Implications and Recommendations..... 9

Bibliography..... 13

EXHIBITS

Exhibit 4.1 The Technology Life-Cycle Concept As Applied to Skill Training..... 10

CHAPTER 4

PUBLIC-PRIVATE INITIATIVES AS A POLICY OPTION FOR IMPROVING OCCUPATIONAL EDUCATION

Introduction

In his recent book, Innovation and Entrepreneurism, author Peter Drucker (1985) discusses what he calls "the emerging 'Fourth Sector' of public-private partnerships [for] better service and substantially lower costs." Public-private partnership may be defined as "cooperation among individuals and organizations in the public and private sectors for mutual benefit.... the participants [also] contribute to the benefit of the broader community while promoting their own individual or organizational interests" (The Committee for Economic Development, 1982, pg.2). This chapter describes the history of this approach to public policy and the potential viability of using community college (public)/business and industry (private) initiatives or partnerships to improve the efficiency, effectiveness, and futures-responsiveness of vocational education.

The research effort for this chapter consisted of a literature survey, plus interviews with selected experts. Most of the literature research was done online, using the ERIC and ABI/INFORM databases. The following descriptors, after much winnowing, proved most effective: public private, initiative, partnership, two-year college, community college, vocational education, economic development, school business relationship. Interviews were conducted with the following:

- Macey Reasoner, Texas State Job Training Partnership Council
- John Baker, Texas Association of Private Industry Councils
- Barbara Edge and William McDonald, Portland (Oregon) Community College
- Les Cave, Houston Private Sector Initiatives
- Henry McHenry, National Alliance of Business.

History[1]

The history of what has come to be known as public-private initiatives is too lengthy a topic to be fully covered in this document. However, this does not preclude a brief discussion of seminal periods in American history that have influenced the creation, development, or even destruction of public-private initiatives.

The first period ranges from colonial times, to the late 1800s, a period of relative prosperity for most Americans--except of course for the slaves. Few governmental or other sorts of restrictions existed to deter free trade. "Most important, each citizen was free, and among his freedoms was his liberty to mix public and private functions without a sense of conflict." There were no basic divisions between business on the one hand and the people on the other. "In fact, the nineteenth-century political economy was characterized by widespread public assistance to business enterprise through the promotion of canals, railroads, and other `internal improvements'."

Large corporations, particularly those involved in steel and oil, soon dominated the nation's economy. "With the rise of big business, the term 'private enterprise' acquired a different meaning. Where once it had meant liberty and freedom, it now meant danger as well." By and by, the balance between the public and private sectors in the late nineteenth century was drastically altered. "In the U.S., alone of all major market economies, the rise of big business preceded the rise of big government."

Americans became much more critical of each other and themselves in the Progressive era (1901-1914), heralding greater separation between the public and private sectors. "These years brought the high tide of journalistic muckraking, our first

---

[1]The primary resource for this section is "The Public and Private Spheres in Historical Perspective" in Public-Private Partnership New Opportunities for Meeting Social Needs by Harvey Brooks, Lance Liebman and Corinne S. Schelling.

sustained period of obsessive preoccupation with thievery and betrayals of the public trust." The catalyst of this progressive movement was a book by historian Charles A. Beard, An Economic Interpretation of the Constitution. "Beard argued that some of the delegates to the Constitutional Convention stood to profit personally from the adoption of such a document..." Vernon Louis Parrington, one of the most eminent progressive scholars, called the late nineteenth century "the Great Barbecue. The cook was big business, the carcass the American public."

Blame for the Great Crash of 1929, with the ensuing depression, was laid at the door of private enterprise. This only confirmed the anti-business sentiment of the period; Roosevelt's subsequent "New Deal" policies betokened a rise in public-sector activity. These programs sought to drive the "money changers" from the American temple. By the mid-twentieth century, the functional separateness of the public and private sectors had become a mainstay of the American liberal creed.

In the wake of the New Deal, the Fair Deal, and the New Frontier--with the more recent return to laissez-faire economics--public perception of this separateness has remained strong. Yet, the United States throughout its history has depended on such public-private partnerships. "One hundred and fifty years ago, Alexis de Tocqueville cited extragovernmental associations as America's legacy to democracy" (Davis, 1986, pg 1). More recently, both the Carter and Reagan administrations have advocated the use of public-private partnerships.

> "The Carter administration thought of partnerships as joint efforts in which government created improved market conditions for private investment, but the Reagan administration has advanced the idea of privatizing public services so that Federal support can be cut back in these areas" (Davis, 1986, pg. 12).

A Framework for Understanding New Roles That Public-Private Partnerships Might Play in Occupational Education

From the foregoing historical survey, it becomes clear that public-private partnerships are not new. In fact, many professionals have been involved before in some type of public-private partnership without calling it that. The Private Industry Councils, or PICs, are a case in point. The literature survey and interviews revealed three broad categories of public-private collaboration: 1) public hiring private; 2) public/private entrepreneurial; and 3) corporate giving. In the following section, each category has been defined and illustrated with actual cases and discussion of the major reasons why public-private partnerships have been undertaken.

PUBLIC HIRING PRIVATE: A public-sector institution, like a school or government agency, contracts with a for-profit company to undertake one or more specific tasks. The assumption here is that free-market incentives will compel a private company to complete a job in a more efficient manner than a public-sector agency could manage. Recent examples of such partnerships include the hiring of private companies to collect trash or provide fire-protection services.

Case Illustrations: The leasing of publicly owned land to private-development entities is increasing in many U.S. urban areas. While many constraints have limited this practice in the past, the creation of special public-development entities by various municipalities, together with the actual leasing of public land to private developers, has created a basis for public-private development partnerships. In the future, developers and public landowners alike may find that under-utilized, publicly owned urban property can yield substantial public and private benefits. (Web, 1982)

At Hagerstown Junior College (HJC), a project was developed to integrate the college's need for increased enrollment with community-college faculty development and industry's need for

worker retraining. The project involved agreements between HJC and Mack Trucks, the largest employer in the college's service area. The first program developed, the HJC-Mack instructor-exchange program, addressed the need for keeping faculty updated on new technology and processes, which in turn contributes to upgrading the skills of Mack employees. These programs benefit the college by checking enrollment decline; by increasing college personnel's familiarity with industrial training and its applications; and by making faculty aware of the relevance of new technology in the classroom. (Parsons, 1985)

The Funds for Excellence program at Thomas Nelson Community College (TNCC) allows teachers to take time off to enter or re-enter business and industry to update their skills and knowledge; to update and enhance occupational/technical curricula and courses; and to improve communication between the college and area businesses. Recognizing the need for a more effective means of occupational-faculty upgrading than sabbatical leaves, TNCC applied for and received a grant for 1983-84, under the Virginia State Council of Higher Educations's "Funds for Excellence Program." The goal for the initial year of the project was to select faculty members and place them half- to full-time in governmental, business, or industrial situations for a full academic quarter. (Cooper and Cooper, 1985)

PUBLIC-PRIVATE ENTREPRENEURIAL: These are the type of partnerships that develop not from a deficiency in either the public or private sector, but from a recognition that cooperation is the best way to solve particular problems. Though either sector could solve the problem without the help of the other, cooperative efforts allow the participants to pool resources. This creates more elegant and potentially longer-lasting solutions. The many economic development projects of this sort already on record have proved the viability of such partnerships.

Case Illustrations: Most downtown redevelopment projects in the U.S. are the result of joint development partnerships. A particularly successful example of this, the development triangle, musters the support and cooperation of city officials, real-estate developers, and lenders alike. Such an approach allows economic-development goals to be achieved by the community-at-large, rather than by one controlling segment (Stokvis, 1983). Cities such as Pittsburgh, PA; Baltimore, MD; and New York, NY, have successfully used this model for urban redevelopment.

Private Industry Councils (PICS) are legislatively mandated public-private partnerships that connect business and other private-sector organizations with local governmental and educational authorities in 450 U. S. localities nationwide. Their purpose is to make it both feasible and desirable for businesses to rely on governmental employment and training programs. PICs have been successful because they allow businesses to design and implement training programs based on industrial specifications and aimed at the development of productive employees. Increasing productivity, not surprisingly, is the only real incentive to private-sector companies (Small, 1983).

Orangewood Children's Home is a $7.5 million, 70,000-square-foot complex designed to provide a homelike atmosphere for beaten, sexually abused, or abandoned children. It was built with the help of county, city, and federal officials in cooperation with the private sector. The effort was spearheaded by a committee of over 200 community leaders chosen for their individual expertise in a variety of areas. First, it was agreed that the public sector would bear 20% of the total cost; then, the private sector was lobbied for its support. The two-tier effort included a leadership council to coordinate major gifts and a community-wide campaign to attract broad-based support. The campaign had tremendous emotional appeal and received lots of publicity. (Norvell, 1986)

CORPORATE GIVING: Corporations and other local businesses donate money on an ongoing basis to community programs, including those emanating from educational institutions. Contributions are used for facility improvement, new equipment, and scholarships, or else redirected to special programs. In this way, Corporations are becoming more intimately involved in solving social problems that stifle economic development, job creation, productivity and, of course, profitability. By funding education-improvement programs, corporations can positively influence the corporate and community environment.

Case Illustrations: In Minneapolis, MN, companies can contribute 5% of their pretax profits to various local community programs. The city of Minneapolis was a pioneer in the Five Percent Club movement, with forty-five local companies now contributing 5%, and another 15 giving 2%.

In 1985, the Sears-Roebuck Foundation awarded the American Association of Community and Junior Colleges (AACJC) and the Association of Community College Trustees (ACCT) a two-year, $950,000 grant, from the Partnership Development Fund. The awards are designed to enhance collaboration between community, technical, and junior colleges on the one hand, and business/industry/labor, public employers, small businesses, and high schools on the other. Some of the awards and activities made possible by the Partnership Development Fund include:

- 29 partnership-development minigrants to colleges
- Five large planning grants and six smaller grants
- A research-and-publications program
- A collaborative project involving the National Telecommunications Education Committee and various colleges to help them develop relevant curricula for the telecommunications industry

- The Fostering of education-industry-government partnerships: objectives for the future include increasing the number of permanent partnerships, improving economic health for small businesses, and enhancing high school-college collaboration and coordination.

Several major insurance companies, including Aetna Life & Casualty and The Prudential, have entered into partnerships with other agencies and organizations in an effort to address social problems by combining mutual resources. The insurance companies themselves contribute leadership and extensive financial resources to such community partnerships. Following are several examples of the industry's past collaborative efforts in this regard: 1) the establishment of a $2 billion Urban Investment Program; 2) industry-wide investment in the College Endowment Funding Plan; 3) Prudential's collaboration with private financial institutions to save jobs at a General Motors plant; and 4) the Harlem Interfaith Counseling Service's construction of a $4.1 million clinic and care facility. (Karson and Murray, 1983)

When Are Public-Private Partnerships Effective and Useful?

The reasons for cooperation between the public and private sectors, based on the cases we have studied, are as varied as the institutions themselves. However, at least one of three main reasons can be found in each case study to explain why a partnership was formed:

1. Local Community Development - The community's overall economic health affects both the public and the private sector. By contributing to community-wide partnerships of this nature, each sector is taking on more responsibility for the fostering of regional well-being. The coordination of economic development with occupational education is just one example.
2. Greater Good of Humanity - Individuals, and even institutions, form public-private partnerships based on

moral or ethical beliefs. "Pro bono" leadership activities by professionals from both the public and private sectors, whether independently administered or under the aegis of a service organization, are examples of this.

3. Survival - Budget reductions in the public sector and increasing competition in the private sector, together with other trends that betoken the end of reckless entrepreneurship, have forced each group to reevaluate its respective operating procedures. Cost-effective partnerships supporting on-the-job occupational education are one result.

For our purposes, however, the reasons that individuals and institutions participate in public-private initiatives are not as important as the underlying trend toward increased use of this organizational model. In case after case, given the proper encouragement, cooperation between the public and private sectors has increased the benefits for all concerned.

Implications and Recommendations

The continued use of public-private partnerships by community colleges and technical institutes is crucial. With social change serving as a driving force, many traditional relationships and partnerships are forging new frontiers and alliances--an important paradigm to be considered for implementation. Community-college leaders are now looking at their students, their community, and themselves in different ways. No longer can a college or local business thrive without the coordination and integration of resources that each brings to the partnership. This period of assessment and development calls for solutions different from those used in the past, with numerous policy implications and recommendations to be considered in the process.

A major new area of interest where public-private partnerships might be beneficially forged is in the articulation

of technology and skill-training life cycles. This is a concept that is introduced in more detail at the beginning of Chapter 5, but portrayed here as well in order to help you visualize it. (See Exhibit 4.1.)

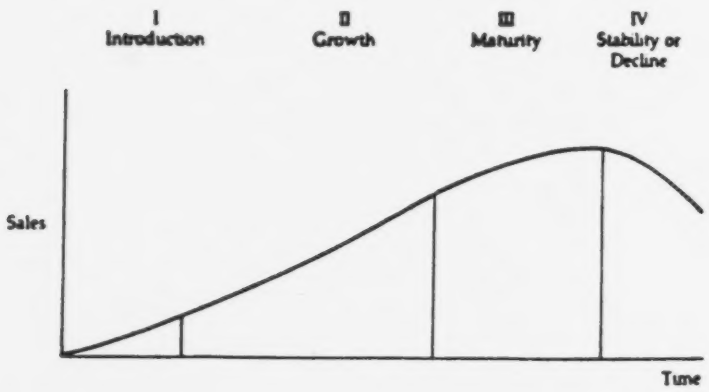
The model indicates that firm-based training is more typical during the Introduction Phase of a new technology while school-based (proprietary as well as public) training is more typical during the Maturity Phase. Therefore, when a new technology requiring new types of training is being introduced by one or more firms in a region, might it not be feasible for public-educational leaders to cooperate with business-industry leaders in formulating anticipatory strategies for training at various stages of the life cycle? The Private Industry Councils (PICs) are a likely mechanism through which this might occur. Other possibilities include: 1)public hiring private or private hiring public for specific types of training at different stages in the maturation process; 2) some type of public-private entrepreneurial training consortium; or 3) corporate giving to public institutions to ensure that they have the wherewithal for advanced-technology training.

In the initial assessment and exploratory stage, when considering the public-private partnership and how best to implement it for a good "fit"--based on the particular situation--existing models should be closely observed. Not that any model should be adopted and copied automatically, but parts of a particular model might be combined with items from another to provide the best "fit" for a particular type of endeavor. As discussed earlier, such partnerships are not a new phenomena; there are numerous models to study and adapt.

During the initial exploratory and needs-assessment phase, all parties benefit from the increased communication and spirit of unity resulting from the collaborative effort. At this juncture, effective networking, marketing, public-relations and communication skills become increasingly important as individuals from both camps come together to shape the

EXHIBIT 4.1
THE TECHNOLOGY LIFE-CYCLE CONCEPT AS APPLIED TO SKILL TRAINING

The Product Life Cycle



Characteristic	Phase			
	I	II	III	IV
Product	Variable, often custom designs	Increasing standardization		Mostly undifferentiated, standardized
Product innovation	Frequent experimentation; major changes	Declining rate		Minor refinements, if any
Volume	Small-scale	Rising volume	Large scale	Large scale
Process	Job-shop, batch production	Increasingly automated	Capital-intensive mass production	Capital-intensive mass production
Process innovation	Exploratory	Relatively high rate, major innovations	Rate declines	Minor refinements, if any
Equipment	General purpose	Increasingly specialized		Special purpose

The Skill-Training Life Cycle

	Phase			
	I Introduction	II Growth	III Maturity	IV Stability or Decline
Tasks	Complex	Increasingly routinized		Segmented
Job skills	Firm-specific	Increasingly general		General
Skill training provider	Employer or equipment manufacturer	Market-sensitive schools and colleges	Schools and colleges more generally	Schools and colleges, some skills provided by employers
Impact on job structures	Job enlargement; new positions	Emergence of new occupations		Rigid job hierarchy with formal education and occupational work experience requirements

Source: Flynn, P. Facilitating Technological Change: The Human Resource Challenge. Cambridge, MA: Ballinger, pp. 12 & 19, 1988.

partnership, assess the mutual benefits, and determine how best they can work together to achieve established goals.

Both parties should agree at the outset to cooperate in achieving these goals. The old saying "two heads are better than one" is certainly appropriate here. Developing bonds of trust and respect early on is crucial, so that interested parties can more readily see the value of their alliance.

Another consideration here is flexibility. Usually, public-sector organizations must follow rigid rules and guidelines to accomplish their objectives. Both parties, though, should act together to minimize or eliminate the negative aspects of such regulation, where possible.

A final consideration when organizing and implementing a public-private partnership is to determine and set forth the goals and objectives of those involved. Too often, individuals enter into partnerships with unexpressed or unrealistic expectations. It is critical, therefore, in the beginning to clarify expectations and goals--especially the short-term, more achievable ones--so that the effort to achieve the more far-reaching objectives of the partnership is not stifled later on.

Public-private partnerships serve as important networking and linking tools for community-college and technical-institute leaders, as well as for business and industry leaders. When thoughtfully organized and developed, such cooperative ventures prove indispensible for meeting the present and future challenges facing education in and for the workplace.

BIBLIOGRAPHY

Ayers, H. Brandt. "The 'Long Arm' Meets the 'Invisible Hand'." The New York Times. February 2, 1987.

Baumol, William J., et al. A New Rationale for Corporate Social Policy. Committee for Economic Development: New York, NY. 1970.

Boatright, Joyce and Crowley, Jacquelin. "An 80's Approach to Providing Educational Services to Business/Industry: The Houston Community College System Plan." A Paper Presented at the National Council for Occupational Education, San Diego, CA. October 15-18, 1986.

Brooks, Harvey, et al. Public-Private Partnership New Opportunities for Meeting Social Needs. Ballinger Publishing Company: Cambridge, MA. 1984.

Bulpitt, Mildred and Lohff, Judith Kaderlik. It's Your Business! Cooperative Efforts Between Community Colleges and Business/Industry. Maricopa Community Colleges: Phoenix, AZ. June 1980.

Callahan, Lois, A. and Steele, Gertrude M. "Securing Business and Industry Support for Community Colleges: A Follow-up Study on the California Association of Community Colleges Commission on Vocational Education 1982 Statewide Vocational Education Study." ACCA Management Report. May 1, 1984

Committee for Economic Development. Public-Private Partnership An Opportunity for Urban Communities. A Statement by the Research and Policy Committee of the Committee for Economic Development. February 1982.

Cooper, John and Hill, John. Funds for Excellence: A college Faculty/Industry Partnership That Works. ERIC ED 253281, 1985.

Davis, Perry. Public-Private Partnerships Improving Urban Life. The Academy of Political Science: New York. 1986.

Drucker, Peter. Innovation and Entrepreneurship: Practice and Principles. New York: Harper and Row, 1985.

Edge, Barbara and MacDonald, William J. "Profitable Partnerships: Public-Private Partners in Economic Development." Portland Community College, Portland, OR. December 10, 1986.

Ellison, Dr. Nolen M., "BICCC: An Important Community College Initiative." Presentation to the BIC Seminar, Kansas Association of Community Colleges, Topeka, KS. January 24, 1983.

Flynn, Patricia M. Facilitating Technological Change: The Human Resource Challenge. Cambridge, MA: Ballinger, pp. 12 & 19, 1988.

Fosler, R. Scott and Berger, Renee A. Public-Private Partnership in American Cities. Lexington Books: Lexington, MA. 1982.

Hargreaves, John and Dauman, Jan. Business Survival and Social Change: A Practical Guide to Responsibility and Partnership. John Wiley & Sons: New York. 1975.

Karson, S. and Murray, B. "An Industry Perspective" Bureaucrat v12 n1 Spring 1983, pp: 23-26.

Kopecek, Robert J. and Clarke, Robert G. Customized Job Training for Business and Industry. Jossey-Bass: San Francisco. December 1984.

Marting, Robert L.. Business & Education: Partners for the Future. Chamber of Commerce National Chamber Foundation, Washington, D.C. January 1985.

Norvell, James. "Abused Children Win Home Through Public-Private Effort." Fund Raising Management. v17 n5 July 1986, pp: 53-61.

Parsons, Michael, A Marriage of Necessity: Professional Development through Business/Industry Articulation. ERIC ED 256471, April, 1985.

Public Relations Journal. "The Need for Business-Municipal Cooperation Is More Urgent Than Ever, and Public Relations Has a Vital Role." September 1982. Page 15-17.

Schilit, Henrietta and Lacey, Richard. The Private Sector Youth Connection Volume I: School to Work. Vocational Education, Inc.: New York, NY. 1982.

Small, Ted and Fischer, Harriet. "Partnerships that Work." Cornell Executive. v9 n2 Spring 1983, pp: 39-42

Stokvis, Jack R. "The Development Triangle: A Partnership for City Economic Revitalization" United States Banker, v94 n12, December 1983, pp:42-46.

Web, Bingham. "Public Land Leasing Comes of Age." National Real Estate Investor. v24 n10, September 1982. Page 24-32.